EFFECTS OF ZINC ON GROWTH AND YIELD OF MUSTARD

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CERTIFICATE

*This is to certify that thesis entitled, "**EFFECTS OF ZINC ON GROWTH AND YIELD OF MUSTARD**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MOST. KAMRUN NAHAR KEYA,** Registration no. **14-06114** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

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DEDICATED TO

MY

BELOVED PARENTS

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EFFECTS OF ZINC ON GROWTH AND YIELD OF MUSTARD

ABSTRACT

A field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period of October-2019 to February 2020 to investigate the effects of zinc on growth and yield of mustard. The experiment conducted in a split-plot design with three replications. The experimental factors were, Factor A: Mustard variety (2) *viz,* V_1= BARI Sarisha-14, V_2= BARI Sarisha-15 and Factor B: Zinc level (6) *viz,* Zn_0 = 0 kg ha^{-1}, Zn_1 = 1.00 kg ha^{-1}, Zn_2 = 2.00 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.00 kg ha^{-1} and Zn_5 = 5.00 kg ha^{-1}.The result showed that the data on growth, yield and yield contributing characteristics of mustard varieties and zinc levels with their combinations were found significant. BARI Sarisha-14 (V_1) produced the maximum number of siliqua $plant^{-1}$ (103.21), siliqua length $plant^{-1}$ (9.78 cm), number of seeds $siliqua^{-1}$ (23.84), 1000-seed weight (3.66 g), seed yield (1.67 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.57 t ha^{-1}) and harvest index (29.90 %). In case of zinc level application of 5.00 kg zinc ha^{-1} (Zn_5) recorded the maximum number of siliqua $plant^{-1}$ (101.83), siliqua length $plant^{-1}$ (9.77 cm), number of seeds $siliqua^{-1}$ (23.84), 1000-seed weight (3.74 g), seed yield (1.82 t ha^{-1}), stover yield (4.07 t ha^{-1}), biological yield (5.89 t ha^{-1}) and harvest index (30.82 %). The interaction affect revealed that the cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua $plant^{-1}$ (116.33), siliqua length $plant^{-1}$ (11.07 cm), number of seeds $siliqua^{-1}$ (27.67), 1000 seed weight (3.89 g), seed yield (1.94 t ha^{-1}), stover yield (4.16 t ha^{-1}), biological yield (6.10 t ha^{-1}) and harvest index (31.79 %) highly positive correlations between seed yield and yield contributing characters of mustard more observed other treatment combinations.

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ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agriculture	Agric.	Milliliter	mL
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
And others	et al.	Triple super phosphate	TSP
Applied	App.	Milligram(s)	mg
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	Cm	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	Cv.	Regulation	Regul.
Degree Celsius	°C	Research and Resource	Res.
Department	Dept.	Review	Rev.
Development	Dev.	Science	Sci.
Dry Flowables	DF	Society	Soc.
East	E	Soil plant analysis development	SPAD
Editors	Eds.	Soil Resource Development Institute	SRDI
Emulsifiable concentrate	EC	Technology	Technol.
Entomology	Entomol.	Tropical	Trop.
Environmment	Environ.	Thailand	Thai.
Food and Agriculture Organization	FAO	United Kingdom	U.K.
Gram	g	University	Univ.
Horticulture	Hort.	United States of America	USA
International	Intl.	Wettable powder	WP
Journal	J.	Serial	Sl.
Kilogram	Kg	Percentage	%
Least Significant Difference	LSD	Number	No.
Liter	L	Microgram	µ

CHAPTER-I

INTRODUCTION

Mustard (*Brassica spp*. L.) is a worldwide cultivated thermo and photosensitive oilseed crop. Asia produces 41.50 % of mustard seed which occupies the first position in terms of percentage share of production followed by the USA (FAO, 2018).

Edible oils play vital roles in human nutrition by providing calories and aiding in digestion of several fat soluble vitamins, for example Vitamin A (National Research Council, 1989). The per capita recommended dietary allowance of oil is 6 gm day^{-1} for a diet with 2700 Kcal (BNNC, 1984). Oilseeds were cultivated in less than 2.20 % of total arable land under rice-based cultivation system in Bangladesh, where three fourth of total cultivable land was engaged in rice production in 2015-16 (BBS, 2019). Mustard is the major oilseeds in Bangladesh which exhibits an increase in production from 1994 to 2018 except few fluctuations in case of total production and area under cultivation (FAO, 2018).

Mustard occupied more than 69.94 % of the total cultivated area of oilseeds in Bangladesh followed by sesame, groundnut, and soybean (BBS, 2019).With the increase in population, the demand for edible oil and oilseeds is in increasing trend (Alam, 2020). Bangladesh has to import a noticeable amount of edible oil and oilseeds to meet up the existing accelerating demand. The value of imported oilseed and edible oil has increased dramatically from USD 544 million in 2002-03 to USD2371 million in 2018-19 which were 4.99 and 4.23 % of the total value of imports respectively (Bangladesh Bank, 2020). Yield of mustard has increased from 0.75 tha^{-1} in 2001 to 1.15 tha^{-1} in 2019 (MoA, 2008; BBS, 2019). Thus in Bangladesh was not in an advantageous position in the case of mustard production (Miah and Rashid, 2015). The inadequate yield of mustard might be grounded by several factors like, lack of high yielding varieties, improper cultural practices, insufficient nutrient management, soil nutrient depletions and so on.

Seed yield and other yield contributing characters significantly varied among the varieties of rapeseed and mustard (BARI, 2001). Uddin *et al.* (1987) reported that there was a significant yield difference among the varieties of rapes and mustard with the same species. *Brassica* (genus of mustard) has three species that produce edible oil, they are *B. napus, B. campestris* and *B. juncea*. Of these, *B. napus* and *B.*

campestris are of the greatest importance in the world's oil seed trade. In this subcontinent, *B. juncea* is also an important oil seed crop. Until recently, mustard varieties such as Tori-7, Sampad (both *B. campestris*) and Doulat (*B. juncea*) were mainly grown in this country. Recently several varieties of high yielding potential characteristics have been developed by BARI for improved production of mustard in Bangladesh.

Crop yield reductions are strongly related with soil quality degradation, particularly nutrient depletions which can be attributed to either insufficient fertilizer use or imbalanced fertilization (Roy *et al*., 2003; Haque *et al*., 2014; Tan *et al*., 2005; Chaudhary *et al*., 2007). Fertilizers have effect on yield and yield attributes of crops and justified fertilizers and resource use are crucial to maintain productivity of crops (Sultana *et al.*, 2019; Sultana *et al*., 2015). Intensive cropping coupled with cultivation of high yielding varieties has extensively exhausted soil fertility not only in respect of macronutrients but also micronutrients.

Zinc being one of the micronutrients, plays a significant role in the various enzymatic and physiological activities of the plant system. It is also essential for assimilation and N- metabolism. It is important for stability of the cytoplasmic ribosome, cell division, dehydrogenase, proteinase, peptidase enzymes and helps in the synthesis of the protein and carotene (Das *et al*., 2005 and Pandey *et al*., 2006). It also helps in the utilization of phosphorus and nitrogen along with physiology of seed formation (Upadhyay *et al*., 2016). It is a micronutrient and in case of its severe deficiency the symptoms may last throughout the entire crop season (Asad and Rafique, 2000).

Zn deficient plant also appears to be stunted. Better zinc nutrition of crop helped in branching both primary and secondary branches resulting in higher stover yield at harvest (Torun *et al*., 2000). The grain yield can be improved by addition of Zn fertilization (Maqsood *et al*., 2009). A researcher also suggested that the application of Zn has become necessary for improved crop yields (Kutuk *et al*., 2000).

Keeping this in view, the present research was undertaken to investigate the effects of zinc on growth and yield of mustard with the following objectives:

i. To evaluate the performance of mustard varieties.
ii. To evaluate the effect of zinc fertilizer rate on growth and yield of mustard varieties.
iii. To determine the combined effect of variety and different zinc fertilizer rate on growth and yield of mustard.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to the effects of zinc on growth and yield of mustard, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of mustard varieties

Plant height

Das *et al.* (2019) reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical makeup. Tyeb *et al.* (2013) reported that the variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic makeup of the cultivars. Rashid *et al.* (2010) conducted a field experiment to find out the effect of the different levels of fertilizers on the growth parameters of mustard varieties of BARI sharisa-9 (V_1), BARI sharisa-12 (V_2) and BARI sharisa-15 (V_3), and to find out the optimum and economically viable fertilizer dose and reported that variety BARI sharisa-15 is of the tall plant type and that others are of intermediate and short stature in plant height. The significant difference in plant height might be associated with the variety characteristics or genetic makeup of the plant. Sana *et al.* (2003) reported that, the final plant height reflected the growth behavior of a crop.

Number of branches

Helal *et al.* (2016) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop. Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15.

Sana *et al.* (2003) reported that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop.

Dry matter accumulation

Helal *et al.* (2016) conducted an experiment of rapeseed-mustard at the Agronomy Research field of Sylhet Agricultural University, Sylhet, during the Rabi season to identify the suitable short durable variety for utilizing the fallow land of Sylhet region that remain fallow after harvest of T. Aman rice. Eight varieties (Improved Tori, TS-72, BARI Sarisha-8, BARI Sarisha-9, BARI Sarisha-12, BARI Sarisha-14, BARI Sarisha-15, and Binasarisha-4) and four promising lines (BC-05115 Y, BC-05117 Y, BC-05118 Y and Nap-205) of rapeseed-mustard were evaluated. Results indicated that, dry matter production pattern at different days after sowing showed that different varieties varied their dry matter production pattern. These variations were noticed from one stage to another stage and none of the variety/line followed the same pattern at different days of sampling. It indicated that each variety/line responded independently from one stage to another stage to the environment in respect of growth of plant, branching and leaf number and ultimately differed in dry matter production. Rashid *et al.* (2010) noticed significant variation in dry matter (DM) accumulation for different mustard varieties on all days after sowing. This might be due to the different varieties which produced a different type of siliqua, and thus, the DM varied significantly.

Number of siliqua per plant

Alam *et al.* (2014) was conducted a field experiment at the Central Research Station of BARI, Gazipur for two consecutive years 2010-11 and 2011-12 with 30 varieties/ genotypes of rapeseed-mustard under three dates of sowing viz., 25 November, 5 December, and 15 December to determine changes in crop phenology, growth and yield of mustard genotypes under late sown condition when the crop faced high temperature. Varieties/genotypes of mustard used in the experiment exerted significant influence on yield and yield attributes and among different varieties maximum number of siliquae/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. This has contributed to higher yield. The lowest number of siliquae/plant (52.0 and 56.3) were found in BARI Sarisha-14.

Mamun *et al.* (2014) found that the number of siliqua plant^{-1} of mustard was significantly affected by different varieties. Singh *et al.*, (2001) conducted an experiment in Jodhpur and observed that number of siliqua/plant recorded higher in cultivar Pusa Bold (257) compared to cultivar TS9 (198). Yadav *et al.* (1978) suggested that for ensuring high yields in *B. juncea*, the plant type should have more number of siliqua/plant (100-125).

Length of siliqua

Hossain *et al.* (1996) reported that the varieties of rapeseed differed significantly in respect of siliqua length. The longer siliqua was found in hybrid BGN-900 (7.75 cm) that was similar to Hyole-101, Sampad, Dhali and Hyola-51.

Number of seeds siliqua^{-1}

Rahman *et al*. (2019) carried out an experiment at Sher-e-Bangla Agricultural University Farm, Dhaka- 1207, Bangladesh during Rabi season, November 2017 to February 2018 to find out the effect of different sowing methods and varieties on the yield of (Brassica campestris). The experiment comprised of two factors - the treatment consisted of four sowing methods viz. S_0 = Broadcast method, S_1 = Line to line space 20 cm, S_2 = Line to line space 25 cm and S_3= Line to line space 30 cm and three different varieties viz. V_1 = BARI Sarisha 14, V_2 = BARI Sarisha 15 and V_3 = BARI Sarisha 17. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. Result revealed that the maximum number of seed per silliqua (23.12) was produced in V_2 (BARI Sarisha 15) treatment and the minimum number of seed per silliqua (18.82) was produced in V_1 (BARI Sarisha 14) treatment. Helal *et al.* (2016) observed significant variations in terms of number of seeds siliqua^{-1} among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity.

1000-seed weight

Mamun *et al.* (2014) carried out a study on the performance of rapeseed and mustard varieties grown under different planting density and observed that BARI Sarisha-13 had the highest 1000- seed weight (4.00 g) whereas the lowest (2.82 g) - in SAU Sarisha-3. Mondal and Wahab (2001) described that, weight of 1000 seeds varied from variety to variety and species to species.

Seed yield

Biswas *et al.* (2019) conducted an experiment at Sher-e-Bangla Agricultural University farm to evaluate the performance of five rapeseed and mustard varieties under two different planting techniques. The planting techniques were as conventional sowing and sowing seeds in puddle soil that assigned to the main plot and five varieties *viz*. Improved Tori-7, BARI Sarisha -13, BARI Sarisha -15, BARI Sarisha -16 and SAU SR-3 in the sub-plots. Result revealed that mustard varieties significantly affect seed yield and among different varieties higher seed yield (2.24 t ha^{-1}) was observed in Improved Tori-7 variety which was followed by BARI Sarisha-16 (1.96 t ha^{-1})) and BARI Sarisha-13 (1.57 t ha^{-1}). The lowest seed yield (1.34 t ha^{-1}) was obtained from V_3 (BARI Sarisha-15) which was statistically similar with SAU SR-3 (1.53 t ha^{-1}). Das *et al*. (2019) carried out a field experiment in the CR Farm of Gayeshpur, BCKV, Nadia, West Bengal, India during *rabi* season of 2015-16 and 2016-17 to find out suitable hybrid variety and optimum spacing for different hybrids. Three hybrid varieties of mustard *viz.* Kesari 5111(V1), Kesari 5222(V2) and Kesari Gold(V3) were taken as treatments in the main plot, whereas, four spacing - 30cm × 10cm (S_1), 30cm × 20cm (S_2), 40cm × 20cm (S_3) and 40cm × 30cm (S4) were imposed as subplot treatment. The experiment was conducted in split plot design with 3 replications and repeated in *rabi* seasons for two consecutive years (2015-16 and 2016-17). The results of the experiment revealed that seed yield significantly differ among varieties and the maximum seed yield was recorded in Kesari Gold (1746 and 2153 kg ha^{-1} respectively in 1st and 2nd year) followed by Kesari 5111. Helal *et al.* (2016) reported that the production of higher yield by different varieties might be due to the contribution of cumulative favorable effects of the crop characteristics viz., number of branches/plant, *siliquae*/plant and seeds/siliqua. Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Bio-902 remained at par with RGN-13 and significantly superior as compared to RGN-48 and PBR-357. Bio-902 cultivar produced 8.72 and 23.03 per cent higher yield, respectively, over RGN- 48 and PBR-357. However, RGN-13 and RGN-48 were remained at par with each other and significantly superior over PBR-357. Islam and Mahfuza (2011) conducted an experiment at the research field of Agronomy Division, BARI, Joydebpur, Gazipur during rabi season of 2010-2011. BARI Sarisha-11 produced the highest seed yield (1472 kg ha^{-1}) while BARI Sarisha-14 the lowest

(1252 kg ha^{-1}). The highest mean seed yield was recorded at maturity stage (1480 kg ha^{-1}) and decreased towards green siliqua stage. Zaman *et al.* (1991) who reported that seed yield of mustards were varied with different varieties.

Stover yield

Sultana *et al.* (2009) studied the stover yield for different varieties of rapeseed under study differed significantly. Kollania produced higher stover yield (2159.0 kg ha^{-1}) which was statistically at par with SAU Sarisha-1 (2156.0 kg ha^{-1}) and higher than Improved Tori -7 (1681.0 kg ha^{-1}).

Biological yield

Tobe *et al.* (2013) also reported variation in biological yield among different cultivars of B. napus and showed that cv. Hyola410 produced the highest seed yield (4759 kg ha^{-1}) as compared to cvs. RDF003 (4280 kg ha^{-1})and Sarigol (3628 kg ha^{-1}). Rana and Pachauri (2001) quoted that cv. Bio 902 recorded higher biological yield (7250 kg ha^{-1}) as compared to cv. TERI (OE) M 21 (6850 kg ha^{-1}).

Harvest index

Thakur *et al.* (2021) carried out an investigation on the agronomic evaluation of Mustard (*Brassica juncea* L.) hybrids under agroclimatic conditions of Prayagraj (U.P.) was carried out during Rabi 2019-2020. The field experiment was laid out in Randomised Block Design, replicated four having 5 different variety as treatments. The finding of the experiment indicated that harvest index significantly influenced by different varieties and maximum harvest index (36.95) was observed in T^2 [45S35]. However, treatment T_1 [var. Bullet] found to be statistically at par with T_2 [45S35]. As discussed earlier, the different hybrids have different yield potential, which is the reason for yield variation among different varieties. Lal *et al.* (2020) conducted an experiment was with four mustard varieties (RGN-73, RGN-229, RH-30 and Pusa bold) in two growing environments (open environment and neem shade) to investigate the performance of mustard (*Brassica juncea* L.) varieties under *Azadirachta indica* L. shade and open condition in hot-arid region of Rajasthan and result revealed that the maximum harvest index under RGN-73 (20.8%) was higher but statistical at par with RGN-229 (20.5%), while both varieties were significantly superior than RH-30 (18.9%) and Pusa bold (18.3%). This might be due to genotype characteristics and high yielding potential of the variety. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) reported that variety had a great influence on harvest index.

2.2 Effect of different zinc levels

Plant height

Singh *et al.* (2012) reported that zinc have played a vital role in the vegetative growth especially under low temperature ambient and rhizosphere regime and adequate availability of zinc to young and developing plants resulting in sufficient growth and development. Ali *et al.* (2011) reported that the increase in growth parameter, chlorophyll contents, biochemical profile and yield components were improved with micronutrient use and found to be dose dependent. Phillips (2004) reported that the micronutrient acts as catalyst in the uptake and use of certain other macronutrients which helps in growth and development of the crops. Prasad *et al.* (2003) observed that with the application of Zn at the rate of 5 kg ha^{-1} produced the highest growth of mustard.

Number of Branches

Shehu (2014) conducted field experiment during the 2005 and 2006 at the food and agricultural organization, tree crop programme teaching and Research farm of the adamawa state university, Mubi to assess the effects of Mn and Zn on shoot content, uptake and utilization of NPK in sesamum (*Sesamum indicum* L.) the treatment consist of N, P and K (75 kg N, 45 kg P_2O_5 and 22.5 kg K_2O ha^{-1}) and various rates of Mn and Zn as:NPK + 0.5 kg Mn ha^{-1}, NPK + 0.5 kg Zn ha^{-1} and NPK + 1 kg Mn ha^{-1}+ 1 kg Zn ha^{-1}, NPK + 1 kg Zn ha^{-1} ,NPK + 0.5 kg Mn ha^{-1} + 0.5 kg Zn ha^{-1} and NPK + 1 kg Mn ha^{-1} + 1 kg Zn ha^{-1} were the treatments combinations. Result shows that stem height, number of branches, leaves were not significantly influenced by Mn and Zn. Jat *et al.* (2012) conducted the field experiment during the rabi season of 2001-02, 2002-03. The level of Zn were employed at 2.5 and 5.0 kg Zn ha^{-1} and found significant increase in a per plant, all the yield attributes (siliqua $plant^{-1}$, seed $siliqua^{-1}$ and test weight) yield (seed and stover) increased significantly with increasing rates of Zn upto 5.0 kg ha^{-1} application. Khan *et al.* (2003) reported that the application of zinc at the rate of 7.5 kg ha^{-1} in mustard significantly increased the number of primary and secondary branches plant^{-1} over the control.

Dry matter accumulation

Kalala *et al.* (2016) reported that application of Zn @ 10 mg kg^{-1} soil enhanced the dry matter yield in rice. Mousavi (2011) reported that foliar or soil application of Zn increases the biosynthesis of chlorophyll which are important for the photosynthetic process which helps physiological activities of the plant and increasing dry matter. Pooniya and Shivay (2011) reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.

Number of siliqua plant^{-1}

Rimi *et al.* (2015) carried out an experiment on rapeseed with four level of N viz. 0, 60, 120, and 180 kg ha^{-1} and three level of Zn 0, 1 and 2 kg ha^{-1} and found singnificant increase in zinc level gradually increasing no. of siliqua per plant and 1000 seed weight. Sahito *et al.* (2014) conducted field experiment to study the effect of micronutrient (Zn) on growth and yield of mustard variety and reported that the application of Zn at the rate of 10 kg ha^{-1} produced maximum number of pods (574.50) plant^{-1}, followed by Zn application at the rates of 8 kg and 6 kg ha^{-1}, producing 569.67 and 548.67 average number of pods plant^{-1}, respectively. The number of pods reduced to 516.67 and 510.67 plant^{-1} when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. Husain and Kumar (2006) reported that zinc application at the rate of 15 kg Zn ha^{-1} significantly increased plant height, number of green leaves, branches and siliqua plant^{-1} of mustard.

Length of siliqua

Singh and Pandey (2017) conducted a field experiment was during 2014-15 with mustard (*Brassica* spp. L.) as a test crop under irrigated conditions on sandy clay loam soils with 4 levels of sulphur (0, 15, 30 and 45 kg ha^{-1}) and 3 levels of zinc (0, 2.5 and 5.0 kg ha^{-1}) in Factorial Randomized Block Design with three replications and concluded that siliqua length increased with increasing zinc levels and maximum siliqua length (3.94 cm) was observed with 5.0 kg Zn ha^{-1} which was significantly higher to control and 2.5 kg Zn ha^{-1}. Khan *et al.* (2003) reported that, length of siliqua of mustard was increased with increasing the level of zinc upto 7.5 kg ha^{-1}.

Number of seed per siliqua

Sipal *et al*. (2016) carried out an experiment on four levels of sulphur (0, 20, 40, 60 kg ha^{-1}) and 3 levels of zinc (0, 2.5, 5.0 kg ha^{-1}) and two levels of FYM (0 and 10 t FYM ha^{-1}) and found significant increase in growth and yield attributes of mustard due to sulphur 60 kg ha-1and zinc 5 kg ha^{-1}. Jat *et al*. (2012) conducted a field experiment during the winter (rabi) seasons of 2001-02 and 2002-03 to study the effect of sulphur and zinc on growth, chlorophyll content, yield attributes and yield of Indian mustard [*Brassica juncea* (L.) *Czern and Coss*]. Increasing levels of zinc significantly increased number of branches per plant, yield attributes (siliquae /plant, seeds /silique and test weight) and yield (seed, stover and biological yield) of Indian mustard during both the years of experimentation. Experiment result revealed the application of 7.5 Zn kg ha^{-1} recorded maximum number of seed per siliqua (16.76 and 17.38) comparable to other treatment. The increase in yield attributes is due to increased supply of available zinc to plants resulting in proper growth and development of plant system. Zinc have role in biosynthesis of Indole acetic acid and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting.

1000-seed weight

Sultana *et al.* (2020) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to evaluate the response of sulphur and zinc nutrition to the seed yield and oil content of mustard (cv. BARI Sarisha-14). It, laid out in RCBD with three replications was consisted of four levels of sulphur (0, 20, 40 and 60 kg ha^{-1}) and Zn (0, 1, 2, 3 kg ha^{-1}). Experiment result showed that increasing zinc fertilization gradually increasing 1000 grains weight and maximum 1000 seed weight (3.02 g) was recorded at 3 kg zinc fertilizer application of per hectare. Kumar *et al*. (2018) conducted a field experiment during rabi season of 2016 at Barakachha to evaluate the effect of S and Zn on growth, yield attributes and yield of rapeseed and reported that sulphur with zinc significantly increased 1000-seed weight. Among all treatments, the highest 1000- seed weight (3.27) were shown by

(40 kg S/ha + 10 kg Zn/ha), which was at par with (40 kg S/ha + 5 kg Zn/ha) and were 10.14 % higher than that of control. While control plot showed lowest 1000-seed weight (3.15) among all the treatment. The improved nutritional environment as a result of increased S and Zn supply might have favorably influenced the carbohydrate metabolism. This favorable effect led to increased translocation of photosynthates towards seeds resulting in formation of bold seeds. Kumar *et al.* (2016) reported that application of sulphur, zinc and boron significantly increased the yield attributes such as number of siliquae per plant, seeds per siliqua and test weight and ultimately increases in yield. Quddus *et al.* (2014) reported that the highest 1000 seed weight 16.03 g was obtained from the treatment Zn level 3.0 kg/ha which was significantly higher than that of other treatments.

Seed yield

Kumar *et al*. (2018) conducted a field experiment during rabi season of 2016 at Barakachha to evaluate the effect of S and Zn on growth, yield attributes and yield of rapeseed. The treatments comprised three level of Sulphur 0, 20, and 40 kg ha-1 in combination with zinc at three level 0, 5, and 10 kg ha^{-1}. The result showed that the application of sulphur in combination with zinc in rapeseed significantly influence the growth, yield attributes and yield. Application of 40 kg S ha^{-1} + 10 kg Zn ha^{-1} was found to be best treatment regarding growth, yield attributes and yield of rapeseed. Kumar *et al.* (2016) carried out an experiment with 6 levels of nitrogen doses as factor A (0, 20, 40, 60, 80, 100, 120 kg per ha^{-1}) and 2 levels of zinc fertilizer application as factor B (0 and 20 kg ha^{-1}). Experiment result showed that application of 20 kg ha^{-1} zinc recorded maximum growth, yield and quality of Indian mustard over control plot. Sahito *et al.* (2014) conducted field experiment to study the effect of micronutrient (Zn) on growth and yield of mustard variety. Two varieties were evaluated against six Zn level (0, 2, 4, 6, 8 and 10 kg ha^{-1}). Result indicated that the application of 8 kg Zn kg ha^{-1} recorded higher seed yield. Mishra *et al.* (2016) carried out an experiment with the combination of 0, 15, 20, and 25 kg S ha^{-1} and 0, 5, 7.5 and 10 kg Zn ha^{-1} respectively along with recomonded dose of NPK level on productivity, nutrient content and uptake by mustard. The best treatment combination was found 25 kg S ha^{-1} and 5 kg Zn ha^{-1} along with NPK under rainfed condition of Chitrakoot for obtaining higher seed yield of mustard crop.

Nawaz *et al*. (2012) carried out study on zinc and iron application to optimize seed yield of mustard. With various level of zinc and Fe (0-0, 0-1.5, 0-3, 2.5-0, 2.5-1.5, 2.5-3, 5-0, 5-1.5 kg ha^{-1}) and (5-3 kg ha^{-1}) respectively. Result indicate that the maximum yield response was recorded when 5 kg ha^{-1} zinc was applied. Maqsood *et al.* (2009) reported that the grain yield can be improved by addition of Zn fertilization. Moniruzzaman *et al.* (2008) applied zinc at the concentrations of 0, 2.5, 5.0 and 7.5 kg ha^{-1} and suggested 8 kg Zn ha^{-1} for brassica species for obtaining higher yield. Chen and Aviad (1990) found that application of Zn along with other micronutrients improved soil organic matter and resulted in increasing mustard yields.

Stover yield

Kaur *et al.* (2017) conducted field experiment with application of 60:30:15:20 kg ha^{-1} N: P: K: S either alone or with addition of different doses of zinc and boron. The application of RDF + 10 kg Zn + 2 kg B ha^{-1} though at par with application of RDF + 5 kg Zn ha^{-1} resulted in significant increase in yield attributes viz. siliqua/plant, seed/ siliqua, test weight, seed and stover yield of mustard crop than RDF. Chandra and Khandelwal (2009) reported that application of zinc at the rate of 5 kg ha^{-1} significantly increased the seed and stover yield of mustard over control. Meena *et al.* (2006) reported that the highest seed and straw yields were obtained with the application of enriched Zn and Fe application.

Biological yield

Jat *et al.* (2012) conducted an experiment to study the effect of sulphur and zinc on growth, chlorophyll content, yield attributes and yield of mustard (*Brassica junceae* L.) on clay loam of Rajasthan and reported that the application of sulphur and zinc improved yield attributes of mustard resulted in increase in seed, stover and biological yield of mustard. Baudh and Prasad (2012) evaluated the effect of different doses of sulphur and zinc with NPK and organic manure on growth and productivity of mustard. The level of S and Zn were employed at 0, 20, 40, and 60, kg S ha^{-1} and 0.5, 1.0, 2.0 kg Zn ha^{-1} and 0, 10, 15, 20 q ha^{-1} organic manure respectively. They observed the highest yield, number of capsules, seed output and reproductive capacity with grain and biological yield also increased with increased level of S and Zn at 60, kg S ha^{-1}, 2.0 kg Zn ha^{-1} and 20 q ha^{-1} organic manure respectively.

Harvest index

Kumar *et al.* (2016) conducted a field experiment to observed the effect of nitrogen and zinc fertilizer rates on growth, yield and quality of indian mustard (*Brassica juncea* L.) and reported that application of 5 kg Zn ha^{-1} significantly increased grain and biological yield as well as harvest index of Indian mustard over control.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka to study the effects of zinc fertilizer rate on growth and yield of mustard. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from October-2019 to February 2020.

3.2 Description of the experimental site

3.2.1 Geographical location

The experiment was conducted both in the Central laboratory and Agronomy field of Sher-e-Bangla Agricultural University (SAU). The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.2.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2.3 Soil

The soil texture was silty clay with pH 6.1. The morphological, physical and chemical characteristics of the experimental soil have been presented in Appendix- II.

3.2.4 Climate and weather

The climate of the experimental site was subtropical, characterized by the winter season from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October (Edris *et al.*, 1979). Meteorological data related to the temperature, relative humidity and rainfall during the experiment period of was collected from Bangladesh Meteorological Department (Climate division), Sher-e-Bangla Nagar, Dhaka and has been presented in Appendix-III.

3.3 Test crop

BARI Sarisha-14 and BARI Sarisha-15 were used as test crop variety for this experiment. The important characteristics of this variety is mentioned below:

3.3.1 BARI Sarisa-14

BARI Sarisa-14 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Developed by crossing between Tori and Sonali Sarisha and released, in the year of 2006. Short duration variety, plant height 75-85 cm, leaf light green, smooth, siliqua/plant 80-102, two chambers are present in pod but as like as four chambers. Seed/siliqua 22-26, seed color pink, 1000 seed weight 3.5-3.8 g, crop duration 75-80 days, after harvest aman and before transplant boro It is easily cultivated because of short duration. It's planting in Rabi season from mid October to mid November given yield 1.45-1.60 t/ha having Oil content 44-45%.

3.3.2 BARI Sarisa-15

BARI Sarisa-14 was developed by Bangladesh Agricultural Research Institute (BARI), Gazipur, Bangladesh. Developed by Selection from local germplasm and released, in the year of 2006. Short durated variety, plant height 90-100 cm, siliqua/plant 70-80, two chambers are present in pod, seed/siliqua 20-22, pod is narrow and taller than BARI sarisa-14, seed color yellow, 1000 seed weight 3.25-3.50 g, crop duration 80-85 days, after harvest aman and before transplant boro, it is easily cultivated because of short duration. It's planting in Rabi season from mid October to mid November. Yield given 1.45-1.60 t/ha and Oil content 48-52%.

3.4 Seed collection

Seeds of BARI Sarisha-14 and BARI Sarisha-15, were collected respectively from Oil Seed Research Centre, Bangladesh Agricultural Research Institute, Gazipur.

3.5 Experimental treatment

There were two factors in the experiment namely mustard varieties and different level of zinc fertilizers as mentioned below:

Factor A: Mustard varieties (2) *viz*

V_1= BARI Sarisha-14
V_2= BARI Sarisha-15 and
Factor B: Different zinc levels

Zn_0 = 0 kg ha^{-1}
Zn_1 = 1.00 kg ha^{-1}
Zn_2 = 2.0 kg ha^{-1}
Zn_3 = 3.00 kg ha^{-1}
Zn_4 = 4.00 kg ha^{-1} and
Zn_5 = 5.00 kg ha^{-1}

3.6 Experimental design and layout

The experiment was laid out in split-plot design having 3 replications. Varieties were in main plots and in sub plots there was different zinc fertilization treatment. There were 12 treatment combinations and 36 unit plots. The unit plot size was 5.4 m^2 (2.7 m × 2 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was shown in Appendix- IV.

3.7 Land preparation

The experimental land was opened with a power tiller on Date 5th October, 2019. Ploughing and cross ploughing were done with power tiller followed by laddering. Land preparation was completed on date 6th October, 2019 and was ready for sowing seeds.

3.8 Fertilizer requirement

The following fertilizers with their corresponding rates were applied as followed:

Fertilizers	Quantity/requirement (kg ha^{-1})
Urea	250
TSP	170
MoP	85
Gypsum	150
Boric Acid	10
Cow dung	8000

Source: (BARI Krishi Projukti hatboi-2019 recommendation)

3.9 Fertilizer application

Urea, triple superphosphate (TSP), Muriate of potash (Mop), gypsum, zinc sulphate, boric acid and cow dung were used as sources of nitrogen, phosphorus, potassium, zinc, boron and others nutrient respectively. Total amount of TSP, MP, gypsum, boric acid, cow-dung and one and half amount of urea were applied at final land preparation. Zinc sulphate was also applied during final land preparation according with par treatment requirement. The rest amount of urea was applied during flower initiation of mustard (BARI krishi projukti hatboi-2019 recommendation).

3.10 Sowing of seeds

Seeds were sown at the rate of 10 kg ha^{-1} in the furrow on date 10th October, 2019 and the furrows were covered with the soils soon after seeding. Seeds were being treated with Bavistin before sowing the seeds to control the seed borne disease. The seeds were sown continuously in 25 cm apart rows at about 2-3 cm depth in afternoon and covered with soil and maintaining 25 cm × 25 cm planting configuration.

3.11 Intercultural operations

i) Weeding and Thinning

Weeding followed by thinning were done after 15 DAS and 45 days after sowing.

ii) Irrigation

Irrigation was given in the respective plots to ensure puddle soil. First irrigation was given at 15 days after sowing (DAS) and the second irrigation was given at 40-45 (DAS). A little irrigation was given at 55-60 (DAS).

iii) Application of pesticides

In the experimental field mustard crops were attacked by aphids (*Lipaphis erysimi*. K). Malathion 57 EC at the rate of 2 ml/litre of water was applied for controlling aphids attack in the field. Application of spraying pesticide was done in the afternoon while the pollinating bees were away from the experimental field.

3.12 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant.

3.13 Harvesting and processing

From the experimental field mustard crop was harvested at maturity when 80 % of the siliquae turned into straw yellowish in color. Harvesting was done in the morning to avoid shattering. Boarder line plants were excluded. Crops were harvested from pre demarcated area of 1 m^2 at the centre of each plot at ground level with the help of a sickle for grain and stover yield. Prior to harvesting, five plants were sampled randomly from each plot, were bundled separately, tagged them and brought to a clean cemented threshing floor from which different yield parameters were recorded. The crop was sun dried properly by spreading them over floor and seeds were separated from the siliquae by beating the bundles with the help of bamboo sticks. The seeds thus collected were dried in the sun for reducing the moisture in the seed to about 9% level. The stovers were also dried in the sun. Seed and stover yield were recorded. The biological yield was calculated as the sum of the seed yield and stover yield.

3.14 Data collection

The data were recorded on the following parameters

a) Growth parameters

i. Plant height (cm)
ii. Branches plant^{-1} (no.)
iii. Total dry matter accumulation plant^{-1} (g)

b) Yield contributing characters

i. Siliqua plant^{-1} (no.)
ii. Length of siliqua (cm)
iii. Seeds siliqua^{-1} (no.)
iv. 1000-seed weight (g)

c) Yield characters

i. Seed yield (t ha^{-1})
ii. Stover yield (t ha^{-1})
iii. Biological yield (t ha^{-1})
iv. Harvest index (%)

3.15 Relationship

i. Relationship between zinc levels and seed yield of mustard varieties.

ii. Correlation of seed yield plant^{-1} with siliqua plant^{-1} and 1000-seed weight of mustard varieties along with different zinc levels.

3.16 Procedure of recording data

i) Plant height

The height of the selected plant was measured from the ground level to the tip of the plant at 15, 30, 45 DAS and harvest respectively. Mean plant heights of mustard plant were calculated and expressed in cm.

ii) No. of branches plant^{-1}

The branches plant^{-1} was counted from five randomly sampled plants and recorded data at 30, 45 DAS and harvest respectively. It was done by counting total number of branches of all sampled plants then the average data were recorded. Data were recorded at harvest respectively.

iii) Total dry matter accumulation plant^{-1}

Five plants were collected randomly from each plot at 30, 45 DAS and harvest respectively. The sample plants were oven dried for 72 hours at 70°C and then dry matter content plant^{-1} was determined. Mean dry matter plant^{-1} of mustard plant were calculated and expressed in gram (g) for recording data.

iv) No. siliqua plant^{-1}

Siliqua plant^{-1} was counted from the 5 selected plant sample and then the average siliqua number was calculated.

v) Length of siliqua plant^{-1}

Length of 5 siliquae collected randomly from the sampled plants and the mean length was recorded.

vi) Seeds siliqua^{-1}

Seeds siliqua^{-1} was counted from splitting five siliquae which were sampled from sample plants and then mean value was determined.

vii) 1000-seed weight

1000-seeds were counted which were taken from the seed sample of each plot, then weighed it in an electrical balance and data were recorded.

viii) Seed yield

The mean seed weight was taken by threshing the plants of each sample area and then converted to t ha^{-1} in dry weight basis.

ix) Stover yield

The stover weights of mustards were calculated after threshing and separation of the grains from the plant of sample area and then expressed in t ha^{-1} on dry weight basis.

x) Biological yield

The summation of seed yield and above ground stover yield was the biological yield. Biological yield =Grain yield + Stover yield.

xi) Harvest index

Harvest index was calculated on dry weight basis with the help of following formula.

$$\text{Harvest index (HI \%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

Here, Biological yield = Grain yield + stover yield

3.17 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistix 10 Data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

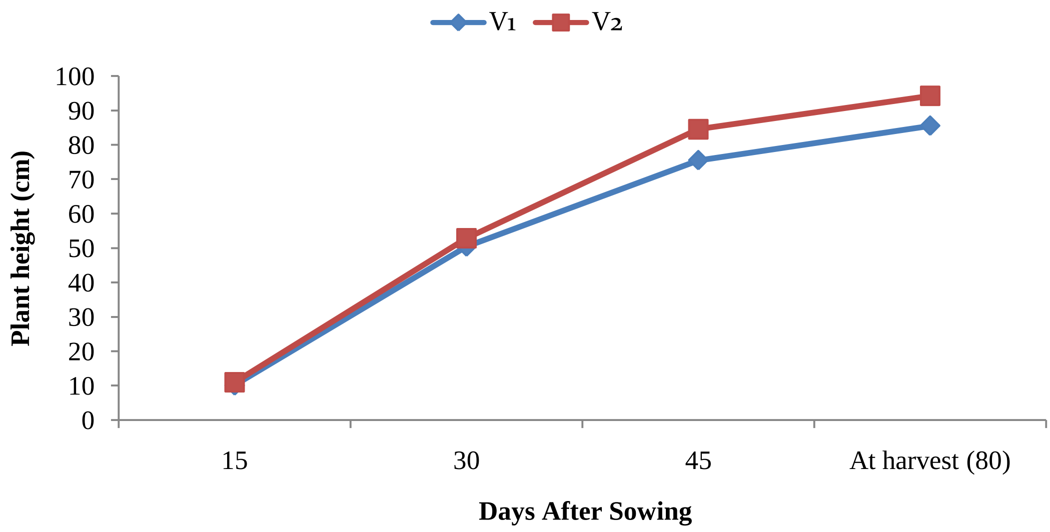
Results obtained from the present study have been presented and discussed in this chapter. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of variety

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach. Different mustard variety significantly differ plant height at different days after sowing (Figure 1). Experiment result revealed that BARI Sarisha-15 mustard variety (V_2) recorded the maximum plant height (10.98, 52.84, 84.53 and 94.25 cm) at 15, 30, 45 DAS and at harvest respectively. Whereas BARI Sarisha-14 mustard variety (V_1) recorded the minimum plant height (10.09, 50.43, 75.53 and 85.55 cm) at 15, 30, 45 DAS and at harvest respectively. The variation in plant height due to the effect of varietal differences. The variation of plant height is probably due to the genetic make-up of the variety. Das *et al.* (2019) and Tyeb *et al.* (2013) also found similar result with the present study and reported that height of a plant is determined by genetical character and under a given set of environment different variety will acquire their height according to their genetical make up. Sana *et al.* (2003) reported that, the final plant height reflected the growth behavior of a crop.

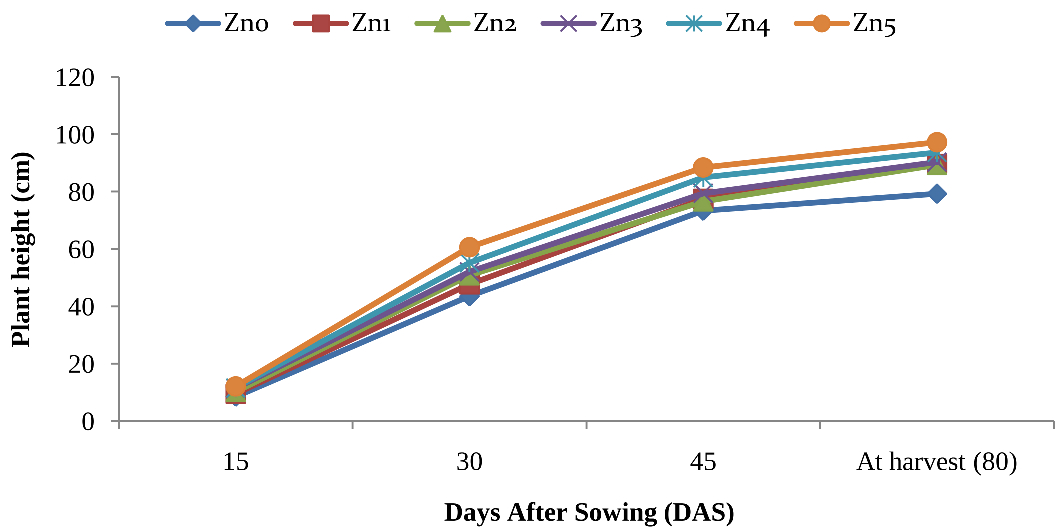


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 1. Effect of variety on plant height of mustard at different DAS ($LSD_{(0.05)}$= 0.42, 0.83, 5.06 and 1.43 at 15, 30, 45 DAS and at harvest respectively).

Effect of zinc levels

Different zinc levels significantly effect on plant height of mustard at different days after sowing. Experiment result revealed, that increasing zinc levels gradually increasing plant height. (Figure 2). Due to variation of zinc levels, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum plant height (12.07, 60.63, 88.44 and 97.26 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded plant height (11.56 and 84.90 cm) at 15 DAS and 45 DAS. Whereas control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum plant height (8.47, 43.48, 73.32 and 79.24 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with 1.00 kg zinc ha^{-1} ($Zn_{1)}$ and 2.0 kg zinc ha^{-1} ($Zn_{2)}$ treated plot recorded plant height (77.43 and 76.67 cm) at 45 DAS. The function of zinc is to help the plant produce chlorophyll. Leaves discolor when the soil is deficient in zinc and plant growth is stunted. Zinc deficiency causes a type of leaf discoloration called chlorosis, which causes the tissue between the veins to turn yellow while the veins remain green. Chlorosis in zinc deficiency usually affects the base of the leaf near the stem causing less photosynthesis, which occur less dry matter production by plant and ultimate impact on growth and development of the plant. The result obtained from the present study was similar with the findings of Singh *et al.* (2012) and they reported that zinc have played a vital role in the vegetative growth especially under low temperature ambient and rhizosphere regime and adequate availability of zinc to young and developing plants resulting in sufficient growth and development. Ali *et al.* (2011) also reported that the increase in growth parameter, chlorophyll contents, biochemical profile and yield components were improved with micronutrient use and found to be dose dependent. Prasad *et al.* (2003) observed that with the application of Zn at the rate of 5 kg ha^{-1} produced the highest growth of mustard.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 2. Effect of zinc levels on plant height of mustard at different DAS (LSD$_{(0.05)}$= 0.67, 1,88, 2.66 and 2.71 at 15, 30, 45 DAS and at harvest respectively).

Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on plant height of mustard at different days after sowing. Experiment result showed that, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum plant height (12.56, 63.43, 97.49 and 103.06 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 4.0 kg zinc ha^{-1} (Zn_4)

treated plot and cultivation of BARI Sarisha-15 mustard variety (V_2) along with 3.00 kg Zinc ha^{-1} (Zn_3) treated plot recorded plant height (12.48 and 12.48 cm) at 15 DAS. Whereas cultivation of BARI Sarisha-14 mustard variety along with 0 kg Zinc ha^{-1} (Zn_0) treated plot recorded the minimum plant height (7.94, 42.24, 63.90 and 71.42 cm) at 15, 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with Zn_0) treated plot recorded the plant height (44.71 cm) at 30 DAS.

Table 1. Combined effect of variety and zinc levels on plant height of mustard at different DAS

Treatment Combinations	Plant height (cm)			
	15 DAS	30 DAS	45 DAS	At harvest (80 DAS)
V_1Zn_0	7.94 f	42.24 h	63.90 f	71.42 h
V_1Zn_1	9.73 c-e	49.10 f	75.12 e	84.88 g
V_1Zn_2	10.37 c	50.98 ef	77.79 c-e	87.93 e-g
V_1Zn_3	10.30 c	49.41 f	77.86 c-e	88.61 d-g
V_1Zn_4	10.63 c	53.00 de	79.12 c-e	89.02 d-f
V_1Zn_5	11.59 b	57.83 b	79.40 c-e	91.46 c-e
V_2Zn_0	9.00 e	44.71 gh	82.74 c	87.06 fg
V_2Zn_1	9.32 de	46.22 g	79.73 c-e	94.33 c
V_2Zn_2	10.01 cd	50.73 ef	75.55 de	90.77 c-f
V_2Zn_3	12.48 ab	54.68 cd	81.03 cd	92.07 cd
V_2Zn_4	12.48 ab	57.27 bc	90.67 b	98.23 b
V_2Zn_5	12.56 a	63.43 a	97.49 a	103.06 a
$LSD_{(0.05)}$	0.95	2.66	5.89	3.83
CV(%)	5.29	3.02	4.32	2.50

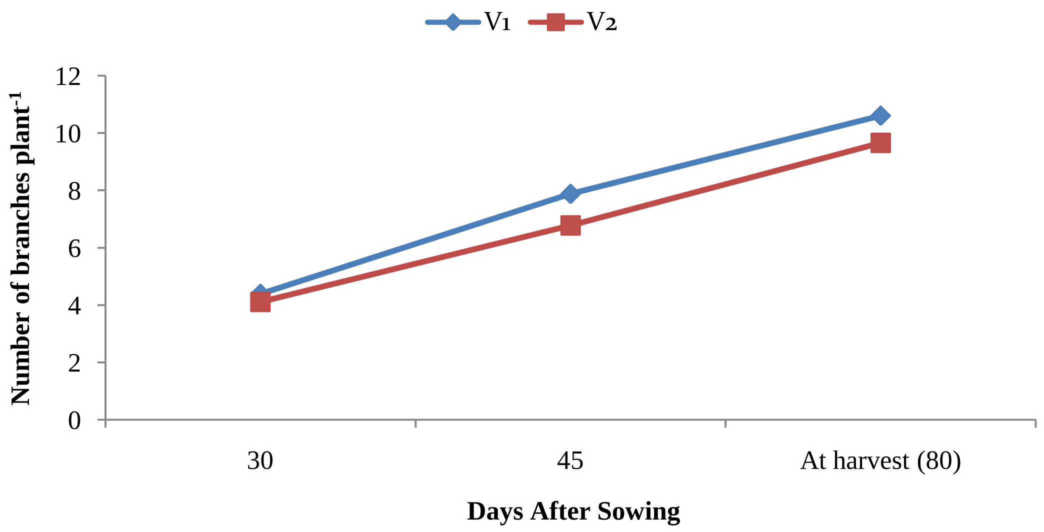
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, Mustard varieties *viz:* V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15 and different zinc levels *viz:* Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.00 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.0 kg zinc ha^{-1}.

4.1.2 Number of branches plant^{-1}

Effect of variety

Different variety significantly effect on number of branches plant^{-1} of mustard (Figure 3). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of branches plant^{-1} (4.39, 7.88 and 10.61) at 30, 45 DAS and at harvest respectively while BARI Sarisha-15 mustard (V_2) variety cultivation recorded the minimum number of branches plant^{-1} (4.11, 6.78 and 9.66) at 30, 45 DAS and at harvest respectively. The reason of difference in number of branches plant^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity. Helal *et al.* (2016) also found similar result which supported the present finding and reported that that higher number of branches/plant is the result of genetic makeup of the crop and environmental conditions which play a remarkable role towards the final seed yield of the crop. Mamun *et al.* (2014) reported that BARI Sarisha-13 produced the highest number of branches plant^{-1} (6.14) which was 33.77% higher (4.59) than BARI Sarisha-15.

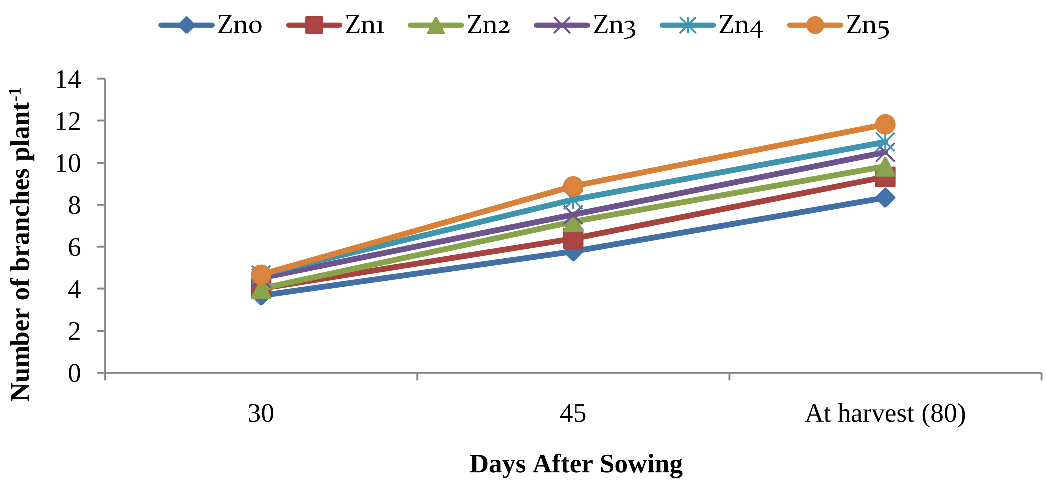


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 3. Effect of variety on number of branches plant^{-1} of mustard at different DAS ($LSD_{(0.05)}$= 0.11, 0.44 and 0.63 at 30, 45 DAS and at harvest respectively).

Effect of zinc levels

Zinc is an important micro nutrient which influences the growth and development of the plant. In this experiment different levels of zinc application significantly impact on number of branches palnt^{-1} of mustard at different days after sowing (Figure 4). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of branches palnt^{-1} (4.67, 8.88 and 11.83) at 30, 45 DAS and at harvest respectively with was statistically similar with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded number of branches palnt^{-1} (4.67) at 30 DAS. Whereas 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of branches palnt^{-1} (3.67, 5.77 and 8.33) at 30, 45 DAS and at harvest respectively. The increase in number of branches palnt^{-1} of mustard might be due to the involvement of sufficient levels of Zn present in soil influence different physiological process of plant like enzyme activation, stomatal regulation and chlorophyll formation etc, which ultimately increase the number of branches palnt^{-1} of mustard. Jat *et al.* (2012) also found similar result which supported the present finding and reported that increasing zinc levels significantly increased yield and yield of mustard. Khan *et al.* (2003) reported that the application of zinc at the rate of 7.5 kg ha^{-1} in mustard significantly increased the number of primary and secondary branches plant^{-1} over control.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 4. Effect of zinc levels on number of branches plant^{-1} of mustard at different DAS (LSD$_{(0.05)}$= 0.10, 0.37 and 0.47at 30, 45 DAS and at harvest respectively).

Combined effect of variety and zinc levels

Combined effect of variety and zinc levels significantly effect on number of branches plant^{-1} (Table 2). Experiment result revealed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of branches plant^{-1} (4.67, 9.87 and 13.33) at 30, 45 DAS and at harvest respectively, which was statistically similar with, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded number of branches plant^{-1} (4.67), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 3.00 kg zinc ha^{-1} (Zn_3) treated plot recorded number of branches plant^{-1} (4.67), with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the number of branches plant^{-1} (4.67) and with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 4.0 kg zinc ha^{-1} (Zn_5) treated plot recorded the number of branches plant^{-1} (4.66) at 30 DAS. Whereas, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of branches plant^{-1} (3.67, 5.29 and 8.00) at 30, 45 DAS and at harvest respectively, which was statistically similar with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.00 kg zinc ha^{-1} (Zn_1) treated plot recorded number of branches plant^{-1} (3.67), with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 2.00 kg zinc ha^{-1} (Zn_2) treated plot recorded number of branches plant^{-1} (3.67), with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded number of branches plant^{-1} (3.67) at 30 DAS; with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded number of branches plant^{-1} (8.66) at harvest respectively.

Table 2. Combined effect of variety and zinc levels on number of branches plant^{-1} of mustard at different DAS

Treatment Combinations	Number of branches plant^{-1}		
	30 DAS	45 DAS	At harvest (80 DAS)
V_1Zn_0	3.67 c	6.25 d	8.66 g
V_1Zn_1	4.33 b	6.37 d	9.66 e
V_1Zn_2	4.33 b	7.71 c	9.66 e
V_1Zn_3	4.67 a	8.52 b	11.00 bc
V_1Zn_4	4.67 a	8.55 b	11.33 b
V_1Zn_5	4.67 a	9.87 a	13.33 a
V_2Zn_0	3.67 c	5.29 e	8.00 g
V_2Zn_1	3.67 c	6.40 d	8.99 f
V_2Zn_2	3.67 c	6.67 d	10.00 de
V_2Zn_3	4.33 b	6.51 d	10.00 de
V_2Zn_4	4.66 a	7.93 c	10.66 cd
V_2Zn_5	4.67 a	7.89 c	10.33 d
$LSD_{(0.05)}$	0.15	0.52	0.66
CV(%)	2.05	4.19	3.83

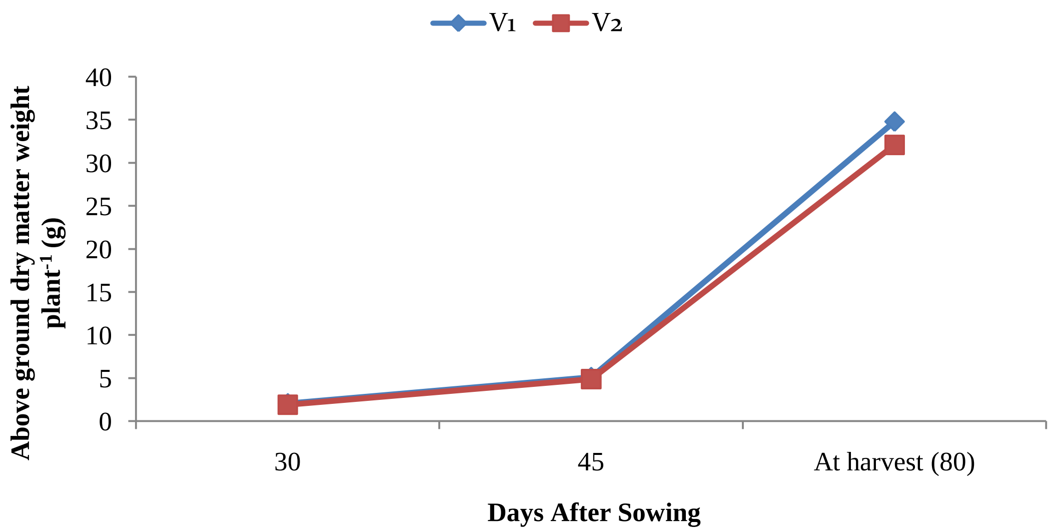
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, Mustard varieties *viz:* V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15 and different zinc levels *viz:* Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.00 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.0 kg zinc ha^{-1}.

4.1.3 Above ground dry matter weight plant^{-1} (g)

Effect of variety

The above ground dry matter weight (g plant^{-1}) differ among different varieties due to reason that individual variety have individual growth stage, and resources utilization its surrounded which influences the above ground dry matter weight (g plant^{-1}). In this experiment result showed that different mustard varieties significantly effect on above ground dry matter weight (g plant^{-1}) of mustard at different DAS (Figure 5). Among different mustard varieties BARI Sarisha-14 mustard variety recorded the maximum above ground dry matter weight plant^{-1} (2.05, 5.10 and 34.79 g) at 30, 45 DAS and at harvest respectively. Whereas cultivation of BARI Sarisha-15 mustard variety recorded the minimum above ground dry matter weight plant^{-1} (1.91, 4.89 and 32.09) at 30, 45 DAS and at harvest respectively. Resources utilization ability had greater in high yielding varieties which influences the dry matter accumulation. The result obtained from the present study was similar with the findings of Helal *et al.* (2016) who reported that each variety/line responded independently from one stage to another stage to the environment in respect of growth of plant, branching and leaf number and ultimately differed in dry matter production. Rashid *et al.* (2010) also reported that the different varieties which produced a different type of siliqua, and thus, the DM (Dry matter) varied significantly.



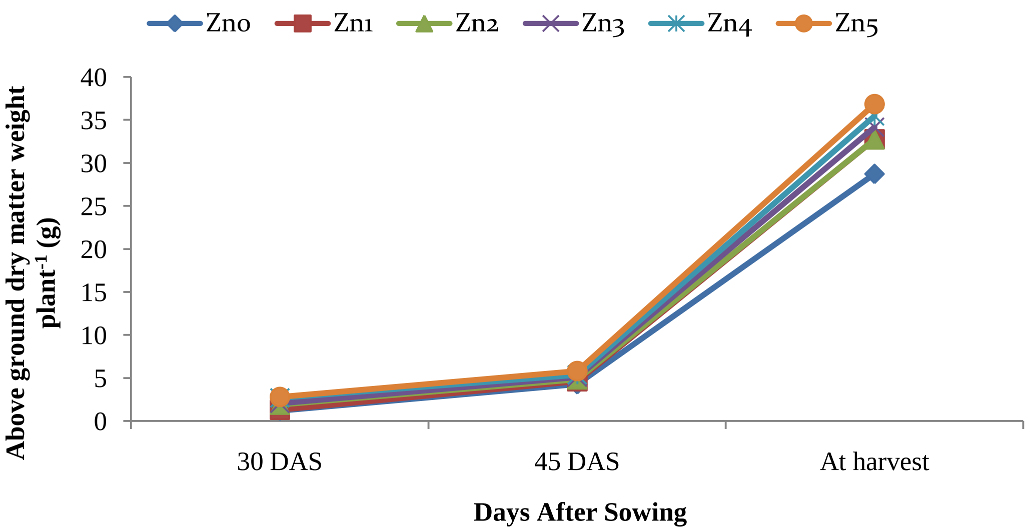
Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 5. Effect of variety on above ground dry matter weight plant^{-1} of mustard at different DAS (LSD$_{(0.05)}$= 0.09, 0.21 and 1.12at 30, 45 DAS and at harvest respectively).

Effect of zinc levels

Different zinc level significantly effect on above ground dry matter weight plant^{-1} (g) of mustard at different DAS (Figure 6). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum above ground dry matter weight plant^{-1} (2.79, 5.81, and 36.84 g) at 30, 45 and at harvest respectively, whereas 0 kg zinc ha^{-1}

(Zn_0) treated plot recorded the minimum above ground dry matter weight plant^{-1} (1.19, 4.26 and 28.72 g) at 30, 45 and at harvest respectively which was statistically similar with 1.00 kg zinc ha^{-1} (Zn_1) treated plot recorded above ground dry matter weight plant^{-1} (1.19) at 30 DAS. Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. Therefore, a constant and continuous supply of zinc is needed for optimum growth and maximum yield. Mousavi (2011) found similar results with the present study and reported that foliar or soil application of Zn increases the biosynthesis of chlorophyll which are important for the photosynthetic process which helps physiological activities of the plant and increasing dry matter. Pooniya and Shivay (2011) also reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 6. Effect of zinc levels on above ground dry matter weight plant^{-1} of mustard at different DAS ($LSD_{(0.05)}$= 0.10, 0.18 and 1.28 at 30, 45 DAS and at harvest respectively).

Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on above ground dry matter weight plant^{-1} (g) of mustard at different DAS (Table 3). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum above ground dry matter weight plant^{-1} (2.93, 5.82 and 38.11 g) at 30 , 45 DAS and at harvest respectively, which was statistically similar with, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded above ground dry matter weight plant^{-1} (5.79 g) at 45 DAS and with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 4.00 kg zinc ha^{-1} (Zn_4) treated plot recorded above ground dry matter weight plant^{-1} (36.88 g) at harvest respectively. Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum above ground dry matter weight plant^{-1} (1.09, 3.94 and 25.63 g) at 30 , 45 DAS and at harvest respectively.

Table 3. Combined effect of variety and zinc levels on above ground dry matter weight plant^{-1} of mustard at different DAS

Treatment Combinations	Above ground dry matter weight plant^{-1} (g)		
	30 DAS	45 DAS	At harvest (80 DAS)
V_1Zn_0	1.28 e	4.57 d	31.81 e
V_1Zn_1	1.29 e	4.66 d	32.94 de
V_1Zn_2	2.09 c	5.21 bc	33.50 de
V_1Zn_3	2.08 c	4.98 c	35.56 bc
V_1Zn_4	2.65 b	5.37 b	36.88 ab
V_1Zn_5	2.93 a	5.82 a	38.11 a
V_2Zn_0	1.09 f	3.94 e	25.63 f
V_2Zn_1	1.29 e	4.52 d	32.56 de
V_2Zn_2	1.72 d	4.49 d	32.00 e
V_2Zn_3	2.03 c	5.24 bc	32.75 de
V_2Zn_4	2.69 b	5.33 b	34.06 cd
V_2Zn_5	2.65 b	5.79 a	35.56 bc
$LSD_{(0.05)}$	0.15	0.26	1.80
CV(%)	4.44	3.06	3.17

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, Mustard varieties *viz:* V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15 and different zinc levels *viz:* Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.00 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.0 kg zinc ha^{-1}.

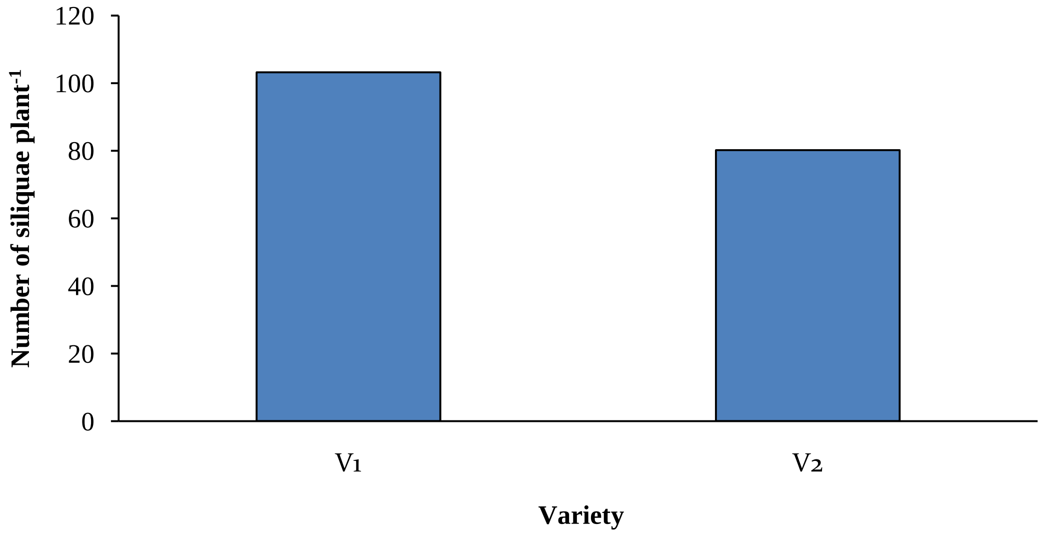
4.2 Yield contributing characters

4.2.1 Number of siliqua plant^{-1}

Effect of variety

Different variety significantly effect on number of siliqua plant^{-1}of mustard (Figure 7). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of siliqua plant^{-1} (103.21) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of siliqua plant^{-1}

(80.18). Different mustard varieties have different number of siliqua plant^{-1} was due to the genetic makeup of the variety and higher number of siliqua plant^{-1} is obtained from high yielding varieties comparable to low yielding mustard varieties. The result obtained from the present study was similar with the findings of Alam *et al.* (2014) who reported that varieties of mustard significantly influence on yield and yield attributes and among different varieties maximum number of siliquae/plant (108 and 90) was recorded in BJDH -05 which differed significantly from other varieties. Mamun *et al.* (2014) also found similar result with the present study and reported that the number of siliqua plant^{-1} of mustard was significantly affected by different varieties.

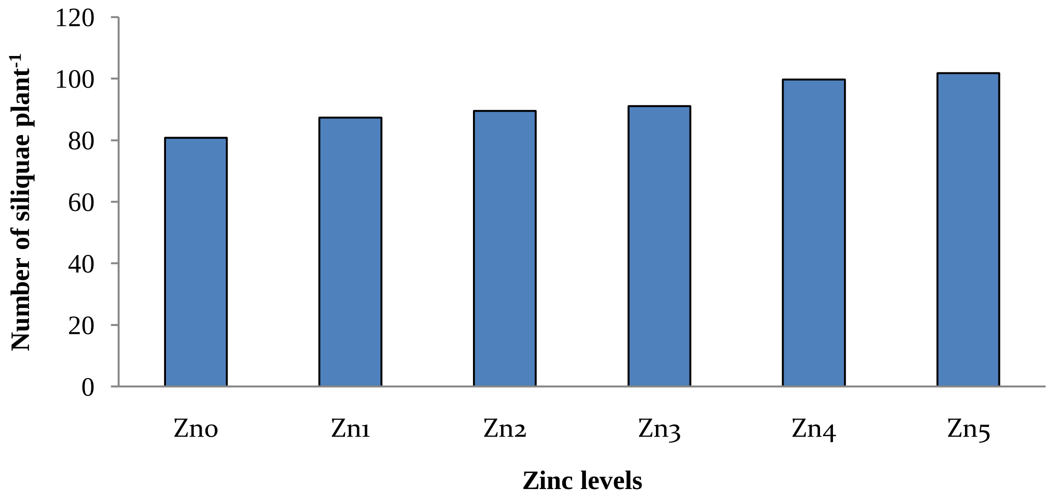


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 7. Effect of variety on number of siliquae plant^{-1} of mustard ($LSD_{(0.05)}$= 1.49).

Effect of zinc levels

Application of different levels of zinc significantly effect on number of siliqua plant^{-1} of mustard (Figure 8). Experiment result showed that, 5.25 kg zinc ha^{-1} (Z_5) treated plot recorded the maximum number of siliqua plant^{-1} (101.83) which was statistically similar with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded the number of siliqua plant^{-1} (99.68), while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of siliqua plant^{-1} (80.77). It is known that Zn physiological function is related to chlorophyll content in plant. Higher chlorophyll content was the cause of the increase in yield characteristics due to the application of zinc, and this apparently had a positive impact on photosynthetic activity, synthesis of metabolites and growth regulating substances, oxidation and metabolic activities, and ultimately improved crop growth and development, leading to an increase in mustard yield characteristics. Rimi *et al.* (2015) found similar results with the present study and reported that increase in zinc levels gradually increasing number of siliqua per plant. Sahito *et al.* (2014) also reported that the number of pods reduced to 516.67 and 510.67 plant^{-1} when Zn was applied at the lower rates of 4 kg and 2 kg ha^{-1}, respectively. Husain and Kumar (2006) reported that zinc application at the rate of 15 kg Zn ha^{-1} significantly increased siliqua plant^{-1} of mustard.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 8. Effect of zinc levels on number of siliquae plant^{-1} of mustard (LSD$_{(0.05)}$= 2.26).

Combined effect of variety and zinc levels

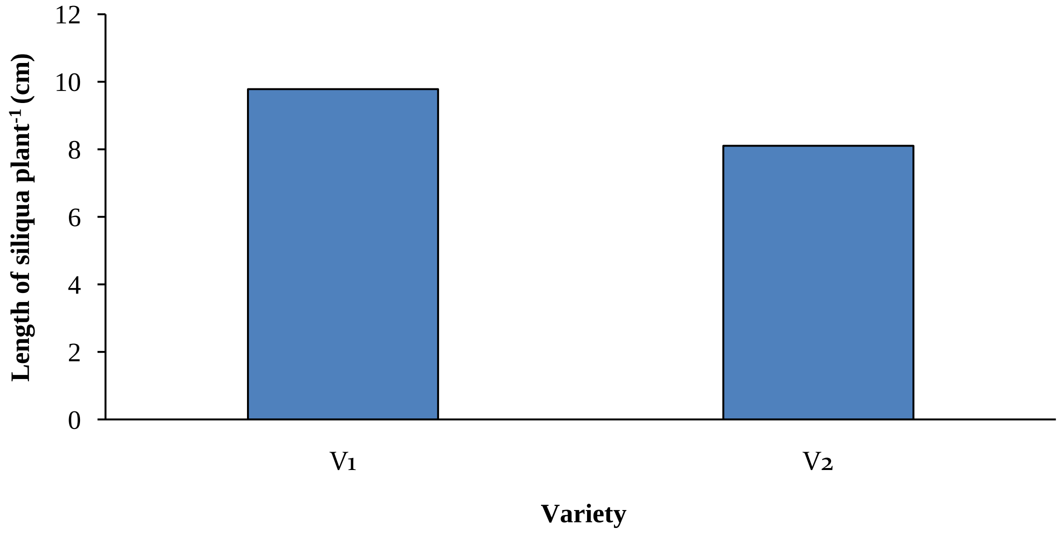
Different mustard variety along with different zinc levels significantly effect on number of siliqua plant^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua plant^{-1} of mustard (116.33) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with

0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of siliqua $plant^{-1}$ of mustard (70.07).

4.2.2 Length of siliqua $plant^{-1}$ (cm)

Effect of variety

Different variety significantly effect on siliqua length $plant^{-1}$ (cm) of mustard (Figure 9). Experiment result showed that cultivation of BARI Sarisha-14 mustard variety (V_1) recorded the maximum siliqua length $plant^{-1}$ (9.78 cm) while cultivation of BARI Sarisha-15 mustard variety (V_2) recorded the minimum siliqua length $plant^{-1}$ (8.10 cm). Different mustard varieties have different siliqua length $plant^{-1}$ was due to the genetic makeup of the variety. The result obtained from the present study was similar with the findings of Hossain *et al.* (1996) and they reported that the varieties of rapeseed differed significantly in respect of siliqua length. The longer siliqua was found in hybrid BGN-900 (7.75 cm) that was similar to Hyole-101, Sampad, Dhali and Hyola-51.

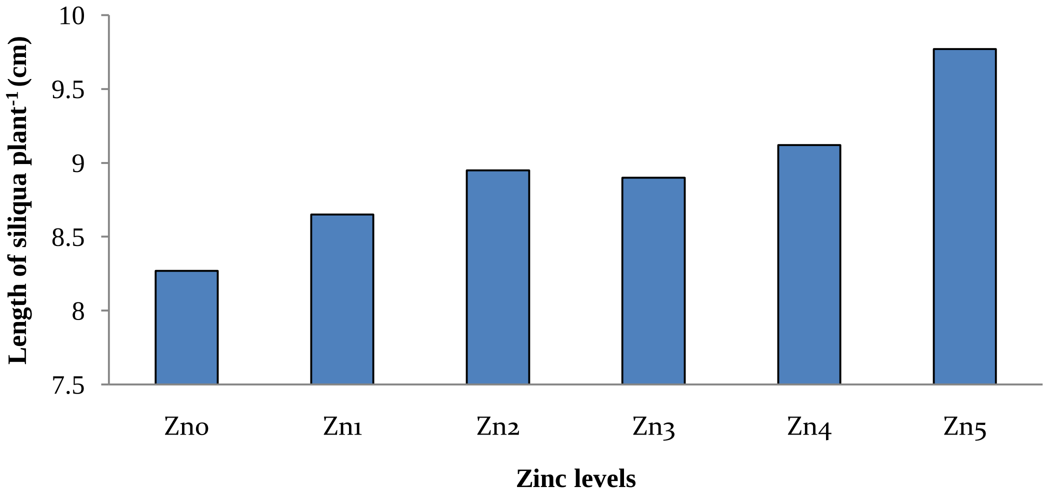


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 9. Effect of variety on length of siliqua $plant^{-1}$ of mustard ($LSD_{(0.05)}$= 0.45)

Effect of zinc levels

Different levels of zinc applied in the experiment field showed significant effect on siliqua length plant^{-1} of mustard (Figure 10). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum siliqua length plant^{-1} of mustard (9.77 cm), while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum siliqua length plant^{-1} of mustard (8.27 cm). Singh and Pandey (2017) also found similar result which supported the present finding and concluded that siliqua length increased with increasing zinc levels and maximum siliqua length (3.94 cm) was observed with 5.0 kg Zn ha^{-1} which was significantly higher to control and 2.5 kg Zn ha^{-1}. Khan *et al.* (2003) also reported that, length of siliqua of mustard was increased with increasing the level of zinc upto 7.5 kg ha^{-1}.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 10. Effect of zinc levels on length of siliqua plant^{-1} of mustard ($LSD_{(0.05)}$= 0.35).

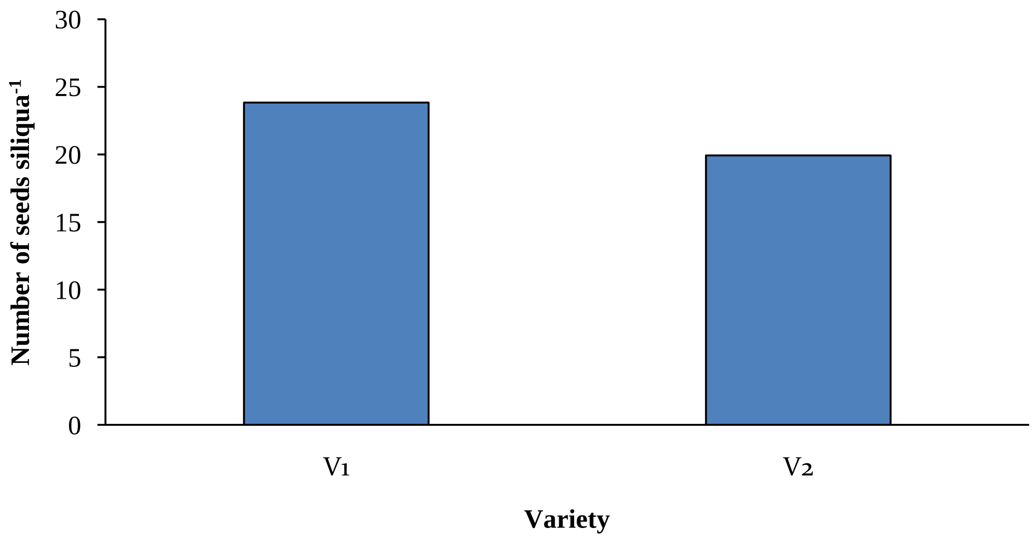
Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on siliqua length plant^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum siliqua length plant^{-1} (11.07 cm) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum siliqua length plant^{-1} (7.47 cm) which was statistically similar with, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.00 kg zinc ha^{-1} (Zn_0) treated plot recorded siliqua length plant^{-1} (7.97 cm).

4.2.3 Number of seeds siliqua^{-1}

Effect of variety

Mustard varieties significantly effect on number of seeds siliqua^{-1} (Figure 11). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of seeds siliqua^{-1} (23.84) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of seeds siliqua^{-1} (19.94). The differences of number of seeds siliqua^{-1} was due to the genetic makeup of the varieties. Similar result observed by Helal *et al.* (2016) and reported that, variations in terms of number of seeds/siliqua among all the varieties due to reason of difference in the genetic makeup of the variety, which is primarily influenced by heredity.

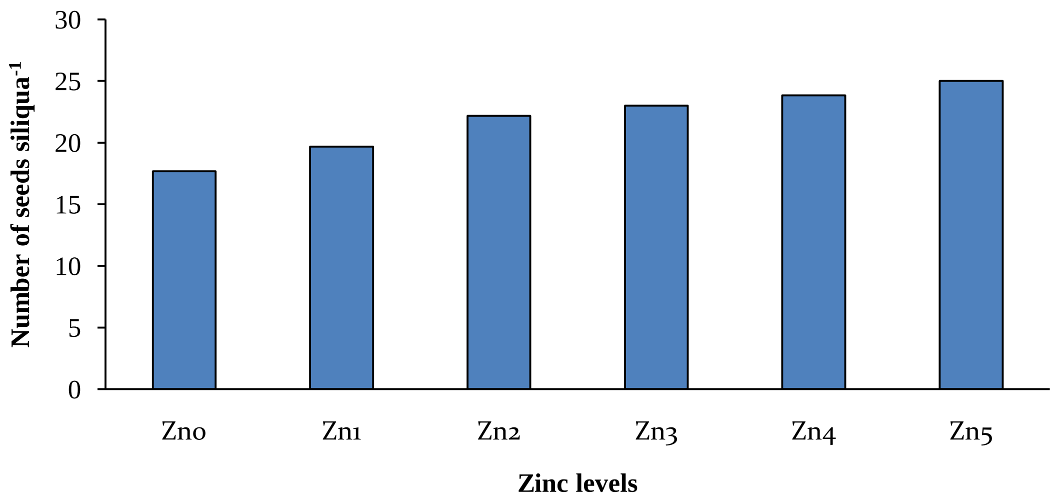


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 11. Effect of variety on number of seeds siliqua^{-1} of mustard ($LSD_{(0.05)}$= 1.90).

Effect of zinc levels

Application of different levels of zinc significantly effect on number of seeds siliqua^{-1} of mustard (Figure 12). Experiment result showed that, 5.25 kg zinc ha^{-1} (Z_5) treated plot recorded the maximum number of seeds siliqua^{-1} of mustard (23.84) which was statistically similar with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded the number of seeds siliqua^{-1} of mustard (23.84), while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of number of seeds siliqua^{-1} of mustard (17.67). It may be attributed to the fact that zinc affects the proteins and metabolism of carbohydrates and this effect is directly related to the processes of sugar conversion and also affects the process of photosynthesis and this has an important role in providing carbohydrates and proteins necessary for the process of growth of vegetative parts and production of reproductive parts. The result obtained from the present study was similar with the findings of Sipal *et al*. (2016) and they found significant increase in growth and yield attributes of mustard due to application zinc @ 5 kg ha^{-1}. Jat *et al*. (2012) also reported that the application of 7.5 Zn kg ha^{-1} recorded maximum number of seed per siliqua (16.76 and 17.38) during the winter (rabi) seasons of 2001-02 and 2002-03 comparable to other treatment.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure. 12. Effect of zinc levels on number of seeds siliqua^{-1} of mustard (LSD$_{(0.05)}$= 1.23).

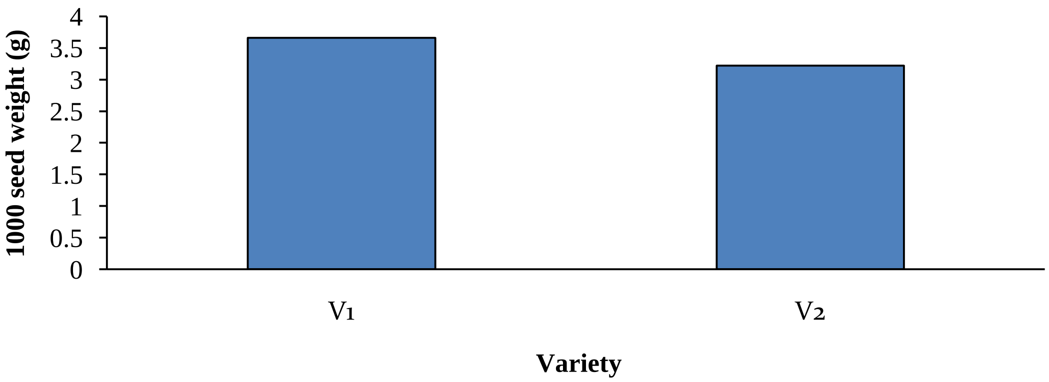
Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on number of seeds siliqua^{-1} of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of seeds siliqua^{-1} (27.67) whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of seeds siliqua^{-1} (16.67) which was statistically similar with, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 1.05 kg zinc ha^{-1} (Z_0) treated plot recorded number of seeds siliqua^{-1} (17.33).

4.2.4 1000 seed weight (g)

Effect of variety

Different varieties significantly effect on 1000 seed weight of mustard. (Figure 13). Experiment result revealed that BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum 1000 seed weight (3.66 g) while BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum 1000 seed weight (3.22 g). The differences of the 1000 seed weight among different mustard varieties may be attributes to the varietal performance and genetic makeup of the varieties. Similar result observed by Mamun *et al.* (2014) who reported that among different varieties BARI Sarisha-13 had the highest 1000- seed weight (4.00 g) whereas the lowest (2.82 g) - in SAU Sarisha-3. Mondal and Wahab (2001) described that, weight of 1000 seeds varied from variety to variety and species to species.

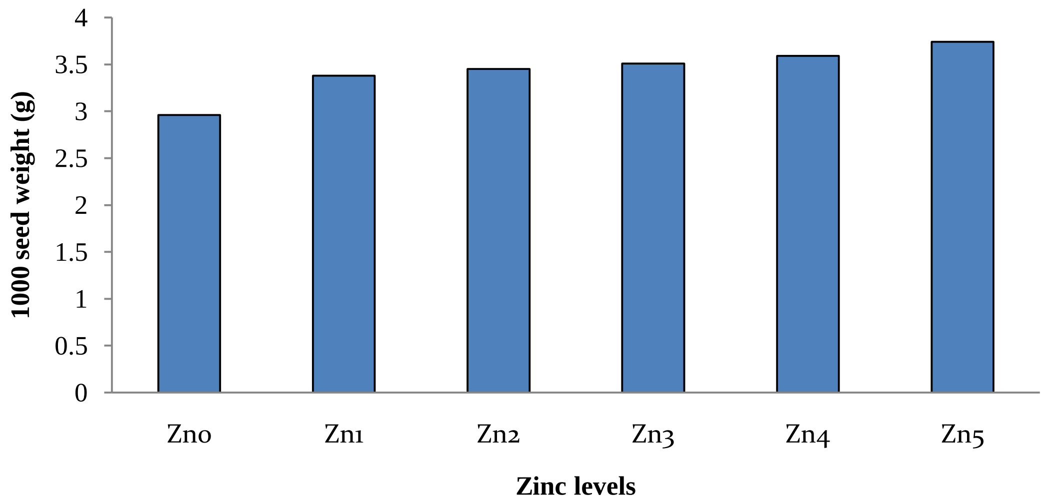


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 13. Effect of variety on 1000 seed weight of mustard ($LSD_{(0.05)}$= 0.07).

Effect of zinc levels

Application of different levels of zinc significantly effect on 1000 seed weight of mustard (Figure 14). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum 1000 seed weight (3.74 g) while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum 1000 seed weight (2.96 g). The increase in yield attributes is due to increased supply of available zinc to plants resulting in proper growth and development of plant system. Zinc have role in biosynthesis of Indole acetic acid and especially due to its role in initiation of primordial for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 14. Effect of zinc levels on 1000 seed weight of mustard ($LSD_{(0.05)}$= 0.14).

Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on 1000 seed weight of mustard (Table 4). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum 1000 seed weight (3.89 g) which was statistically similar with, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 4.00 kg zinc ha^{-1} (Zn_4) treated plot recorded 1000 seed weight (3.76 g) and with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 3.00 kg zinc ha^{-1} (Zn_3) treated plot recorded 1000 seed weight (3.72 g). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum 1000 seed weight (2.50 g).

Table 4. Combined effect of variety and zinc levels on number of siliqua plant^{-1}, length of siliqua plant^{-1}, number of seeds siliqua^{-1} and 1000 seeds weight of mustard

Treatment Combinations	Number of siliqua plant^{-1}	Length of siliqua plant^{-1}	Number of seeds siliqua^{-1}	1000 seeds weight (g)
V_1Zn_0	91.47 d	9.07 c	18.67 fg	3.42 cd
V_1Zn_1	99.33 c	9.33 bc	22.00 c-e	3.55 bc
V_1Zn_2	100.67 c	9.73 b	23.33 c	3.62 bc
V_1Zn_3	100.40 c	9.73 b	25.67 b	3.72 ab
V_1Zn_4	111.03 b	9.77 b	25.67 b	3.76 ab
V_1Zn_5	116.33 a	11.07 a	27.67 a	3.89 a
V_2Zn_0	70.07 h	7.47 e	16.67 h	2.50 f
V_2Zn_1	75.33 g	7.97 de	17.33 gh	3.20 e
V_2Zn_2	78.33 g	8.17 d	21.00 de	3.27 de
V_2Zn_3	81.67 f	8.07 d	20.33 ef	3.30 de
V_2Zn_4	88.33 de	8.47 d	22.00 c-e	3.43 cd
V_2Zn_5	87.33 e	8.47 d	22.33 cd	3.60 bc
$LSD_{(0.05)}$	3.20	0.50	1.74	0.21
CV(%)	2.05	3.26	4.68	3.55

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

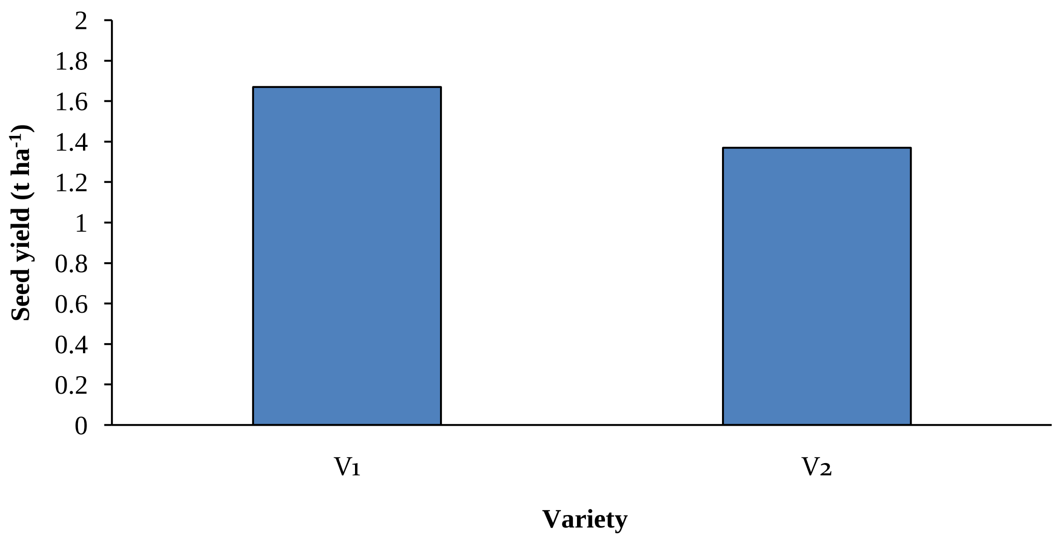
Here, Mustard varieties *viz:* V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15 and different zinc levels *viz:* Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.00 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.0 kg zinc ha^{-1}.

4.3 Yield characters

4.3.1 Seed yield (t ha^{-1})

Effect of variety

Mustard varieties significantly effect on seed yield plant^{-1} (Figure 15). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum seed yield (1.67 t ha^{-1}) while BARI Sarisha-15 mustard variety cultivation recorded the minimum seed yield (1.37 t ha^{-1}). Different mustard variety have individual genetic makeup which influenced the growth and yield among different varieties. Biswas *et al.* (2019) also found similar result which supported the present finding and reported that seed yield differed among different varieties of mustard. Junjariya (2014) reported that seed yield of Indian mustard was influenced significantly with different cultivars. Zaman *et al.* (1991) who reported that seed yield of mustards were varied with different varieties.

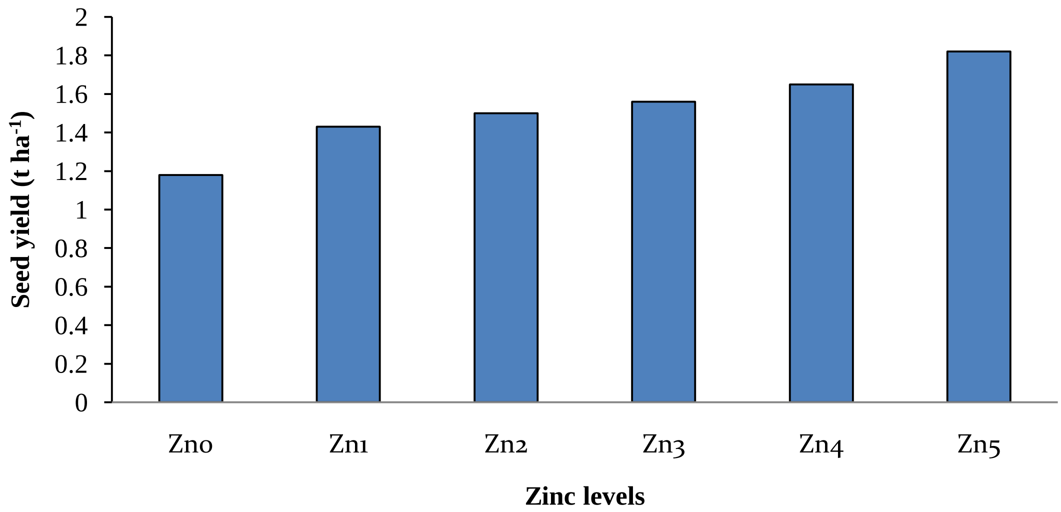


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 15. Effect of variety on seed yield of mustard ($LSD_{(0.05)}$= 0.05).

Effect of zinc levels

Different zinc levels significantly effect on seed yield (t ha^{-1}) of mustard (Figure 16). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum seed yield (1.82 t ha^{-1}) while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum seed yield (1.18 t ha^{-1}). Zinc is an important component of various enzymes that are responsible for driving many metabolic reactions in all crops. Growth and development would stop if specific enzymes were not present in plant tissue. Carbohydrate, protein, and chlorophyll formation is significantly reduced in zinc-deficient plants. Therefore, a constant and continuous supply of zinc is needed for optimum growth and maximum yield. The result obtained from the present study was similar with the findings of Kumar *et al*. (2018) and they reported that the application of sulphur in combination with zinc in rapeseed significantly influence the growth, yield attributes and yield. Application of 40 kg S ha^{-1} + 10 kg Zn ha^{-1} was found to be best treatment regarding growth, yield attributes and yield of rapeseed. Sahito *et al.* (2014) reported that the application of 8 kg Zn kg ha^{-1} recorded higher seed yield. Maqsood *et al.* (2009) reported that the grain yield can be improved by addition of Zn fertilization.Chen and Aviad (1990) also found that application of Zn along with other micronutrients improved soil organic matter and resulted in increasing mustard yields.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 16. Effect of zinc levels on seed yield of mustard ($LSD_{(0.05)}$= 0.08).

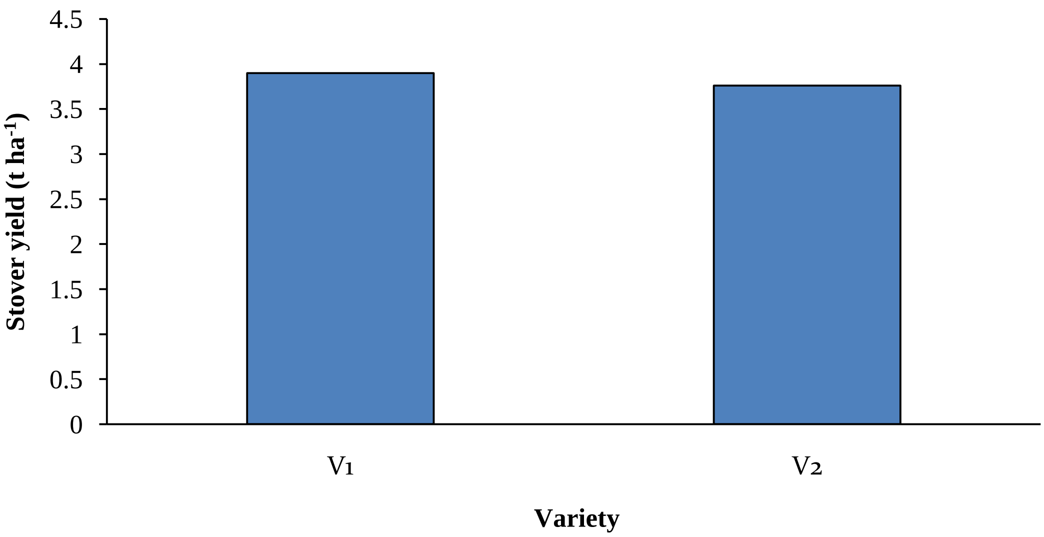
Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on seed yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum seed yield (1.94 t ha^{-1}). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum seed yield (0.93 t ha^{-1}).

4.3.2 Stover yield (t ha^{-1})

Effect of variety

Different varieties significantly effect on stover yield (t ha^{-1}) of mustard (Figure 17). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum stover yield (3.90 t ha^{-1}) while BARI Sarisha-15 mustard variety cultivation recorded the minimum stover yield $plant^{-1}$ (3.76 t ha^{-1}). Sultana *et al.* (2009) also found similar result with present study and reported that stover yield of mustards were varied with different varieties.



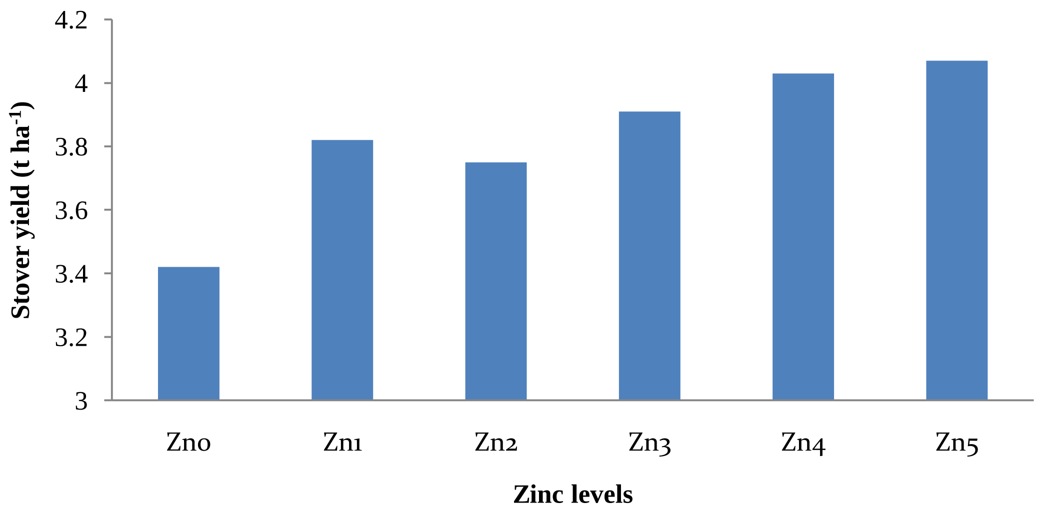
Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 17. Effect of variety on stover yield of mustard ($LSD_{(0.05)}$= 0.13).

Effect of zinc levels

Application of different levels of zinc significantly effect on stover yield (t ha^{-1}) of mustard (Figure 18). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum stover yield (4.07 t ha^{-1}) which was statistically similar with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded stover yield (4.03 t ha^{-1}) while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum stover yield (3.42 t ha^{-1}).

Zinc is one of the essential micronutrients required for optimum plant growth and plays a vital role in metabolism. It is required in small but critical concentration for the functioning of several plants physiological functions like photosynthesis and sugar formation, fertility and seed production, growth regulation and disease resistance. Deficiency of zinc cause malfunction of the plant. Kaur *et al.* (2017) also found similar result which supported the present finding and reported that the application of RDF + 10 kg Zn + 2 kg B ha^{-1} though at par with application of RDF + 5 kg Zn ha^{-1} resulted in significant increase in yield attributes viz. siliqua/plant, seed/ siliqua, test weight, seed and stover yield of mustard crop than RDF. Chandra and Khandelwal (2009) reported that application of zinc at the rate of 5 kg ha^{-1} significantly increased the seed and stover yield of mustard over control. Meena *et al.* (2006) also reported that the highest seed and straw yields were obtained with the application of enriched Zn and Fe application.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 18. Effect of zinc levels on stover yield of mustard ($LSD_{(0.05)}$= 0.13).

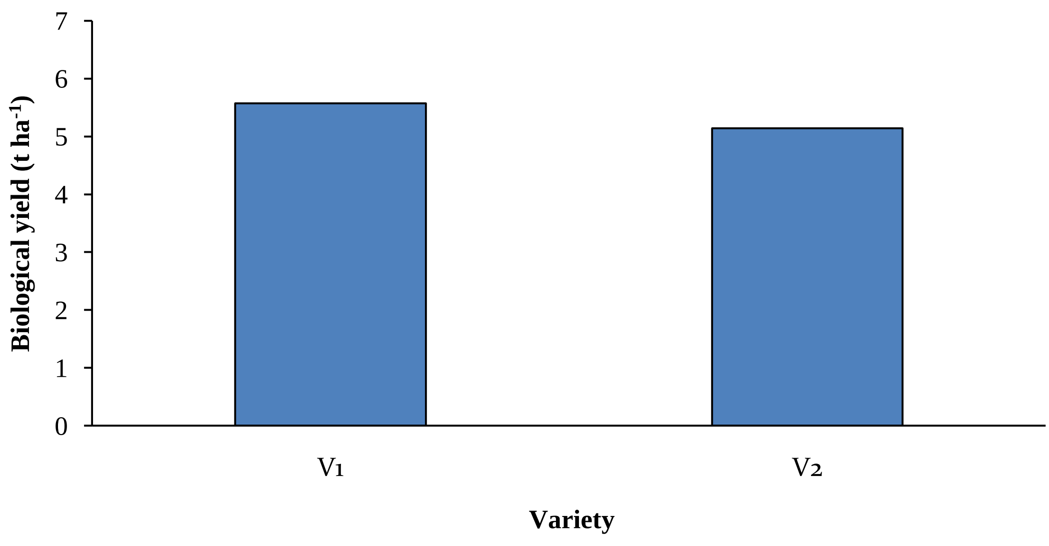
Combined effect of variety and zinc levels

Combined effect of variety and zinc levels significantly effect on stover yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum stover yield (4.16 t ha^{-1}) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded stover yield (4.14 t ha^{-1}) and with cultivation of BARI Sarisha-15 mustard variety (V_2) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded stover yield (3.99 t ha^{-1}). Whereas the cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum stover yield (3.17 t ha^{-1}).

4.3.3 Biological yield (t ha^{-1})

Effect of variety

Different variety cultivation significantly effect on biological yield (t ha^{-1}) of mustard (Figure 19). Experiment result showed that cultivation of BARI Sarisha-14 mustard variety recorded the maximum biological yield (5.57 t ha^{-1}) while cultivation of BARI Sarisha-15 mustard variety recorded the minimum biological yield (5.14 t ha^{-1}). The variation of biological yield by different varieties might be due to the contribution of cumulative favourable effects of the crop characteristics viz., seed and stover yield of the crop. Tobe *et al.* (2013) also found similar result which supported the present finding and reported that variation in biological yield differ among cultivars of *B. napus*. Rana and Pachauri (2001) also quoted that cv. Bio 902 recorded higher biological yield (7250 kg ha^{-1}) as compared to cv. TERI (OE) M 21 (6850 kg ha^{-1}).

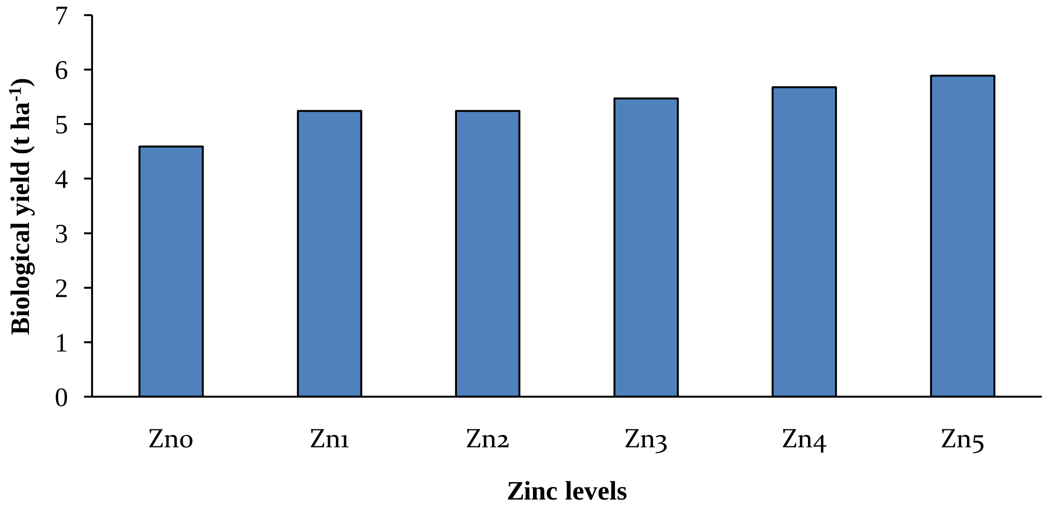


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 19. Effect of variety on biological yield of mustard ($LSD_{(0.05)}$= 0.18).

Effect of zinc levels

Application of different levels of zinc significantly effect on biological yield (t ha^{-1}) of mustard (Figure 20). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum biological yield (5.89 t ha^{-1}) while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum biological yield (4.59 t ha^{-1}). Jat *et al.* (2012) also found similar result which supported the present finding and reported that the application of sulphur and zinc improved yield attributes of mustard resulted in increase in seed, stover and biological yield of mustard. Baudh and Prasad (2012) also observed that the highest yield, number of capsules, seed output and reproductive capacity with grain and biological yield also increased with increased levels of S and Zn at 60, kg S ha^{-1}, 2.0 kg Zn ha^{-1} and 20 q ha^{-1} organic manure respectively.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 20. Effect of zinc levels on biological yield of mustard ($LSD_{(0.05)}$= 0.13).

Combined effect of variety and zinc levels

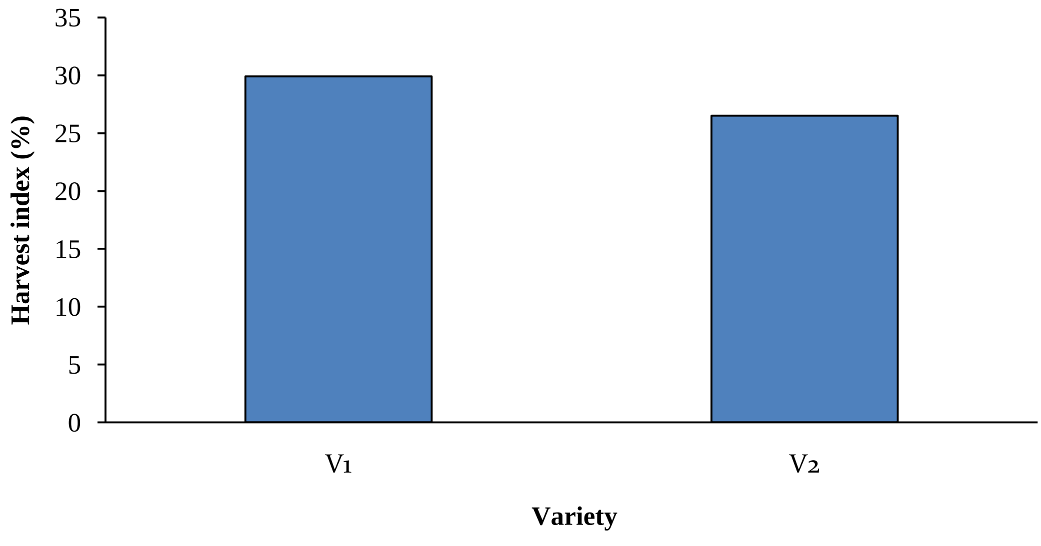
Combined effect of variety and zinc levels significantly effect on biological yield (t ha^{-1}) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum biological yield (6.10 t ha^{-1}) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 4.0 kg zinc ha^{-1} (Zn_4) treated plot recorded biological yield (5.90 t ha^{-1}). Whereas the cultivation of

BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum biological yield (4.10 t ha^{-1}).

4.3.4 Harvest index (%)

Effect of variety

Mustard varieties significantly effect on harvest index (Figure 21). Experiment result revealed that BARI Sarisha-14 mustard variety cultivation recorded the maximum harvest index (29.90 %) while BARI Sarisha-15 mustard variety cultivation recorded the minimum harvest index (26.52 %). The harvest index differed significantly among the varieties due to its genetic variability. Thakur *et al.* (2021) also found similar result which supported the present finding and reported that the different varieties have different yield potential, which is the reason for yield variation among different varieties which ultimately impact on harvest index. Uddin *et al.* (2011) reported that the harvest index differed significantly among the varieties due to its genetic variability. Shah *et al.* (1991) also reported that variety had a great influence on harvest index.

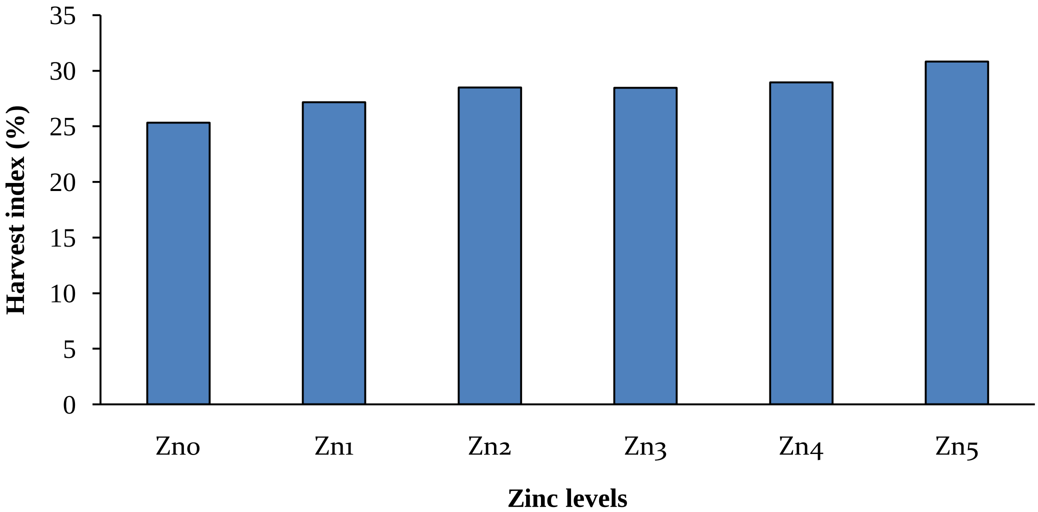


Note: Here, V_1 = BARI Sarisha-14 and V_2= BARI Sarisha-15.

Figure 21. Effect of variety on harvest index of mustard ($LSD_{(0.05)}$= 0.63).

Effect of zinc levels

Application of different levels of zinc significantly effect on harvest index (%) of mustard (Figure 22). Experiment result showed that, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum harvest index (30.82 %) while control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum harvest index (25.32 %). The result obtained from the present study was similar with the findings of Kumar *et al.* (2016) and they reported that application of 5 kg Zn/ha significantly increased grain and biological yield as well as harvest index of Indian mustard over control.



Note: Here, Zn_0 = 0 kg ha^{-1}, Zn_1 =1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 =5.00 kg ha^{-1}.

Figure 22. Effect of zinc levels on harvest index of mustard ($LSD_{(0.05)}$= 1.16).

Combined effect of variety and zinc levels

Different mustard variety along with different zinc levels significantly effect on harvest index (%) of mustard (Table 5). Experiment result showed that, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum harvest index (31.79 %) which was statistically similar with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 3.00 kg zinc ha^{-1} (Zn_3) treated plot recorded harvest index (30.23 %) and with cultivation of BARI Sarisha-14 mustard variety (V_1) along with 2.1 kg zinc ha^{-1} (Zn_2) treated plot recorded harvest index (30.22 %). Whereas the cultivation of BARI Sarisha-15 mustard variety

(V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum harvest index (22.74%).

Table 5. Combined effect of variety and zinc levels on seed, stover, biological yield (t ha^{-1}) and harvest index (%) of mustard

Treatment Combinations	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1Zn_0	1.42 ef	3.67 e	5.09 e	27.90 cd
V_1Zn_1	1.55 d	3.72 e	5.27 c-e	29.41 bc
V_1Zn_2	1.62 cd	3.74 de	5.36 cd	30.22 ab
V_1Zn_3	1.72 bc	3.97 bc	5.69 b	30.23 ab
V_1Zn_4	1.76 b	4.14 ab	5.90 ab	29.83 b
V_1Zn_5	1.94 a	4.16 a	6.10 a	31.79 a
V_2Zn_0	0.93 h	3.17 f	4.10 f	22.74 f
V_2Zn_1	1.30 g	3.91 cd	5.21 de	24.95 e
V_2Zn_2	1.37 fg	3.75 de	5.12 e	26.76 d
V_2Zn_3	1.40 fg	3.84 c-e	5.24 c-e	26.72 d
V_2Zn_4	1.53 de	3.92 cd	5.45 c	28.07 cd
V_2Zn_5	1.70 bc	3.99 a-c	5.69 b	29.85 b
$LSD_{(0.05)}$	0.11	0.18	0.22	1.64
CV(%)	4.44	2.85	2.46	3.42

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Here, Mustard varieties *viz:* V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15 and different zinc levels *viz:* Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.00 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.0 kg zinc ha^{-1}.

4. 4. Correlation of seed yield (t ha^{-1}) with siliqua plant^{-1}, seed siliqua^{-1} and 1000 seed weight (g) of mustard varieties along with different zinc levels

From the (Figure 23, 24 and 25) it was noticed that seed yield of mustard varieties was positively correlated with number of siliqua plant^{-1} (R^2=0.787), number of seed siliqua^{-1} (R^2=0.853) and 1000-seeds weight (R^2=0.953). From the correlation study, it appears that seed yield increase with increasing siliqua plant^{-1}, seed siliqua^{-1} and 1000-seeds weight. In this experiment BARI Sarisha-14 mustard variety cultivation along with increasing zinc fertilization levels @ 5.00 kg ha^{-1} recorded maximum seed yield (1.94 t ha^{-1}) which was due to reason that BARI Sarisha-14 mustard variety along with increasing zinc levels, produce higher number of siliqua plant^{-1} (116.33), seed siliqua^{-1} (27.67) and recoded maximum 1000-seeds weight (3.89) in comparable to others varieties in different levels of zinc fertilization.

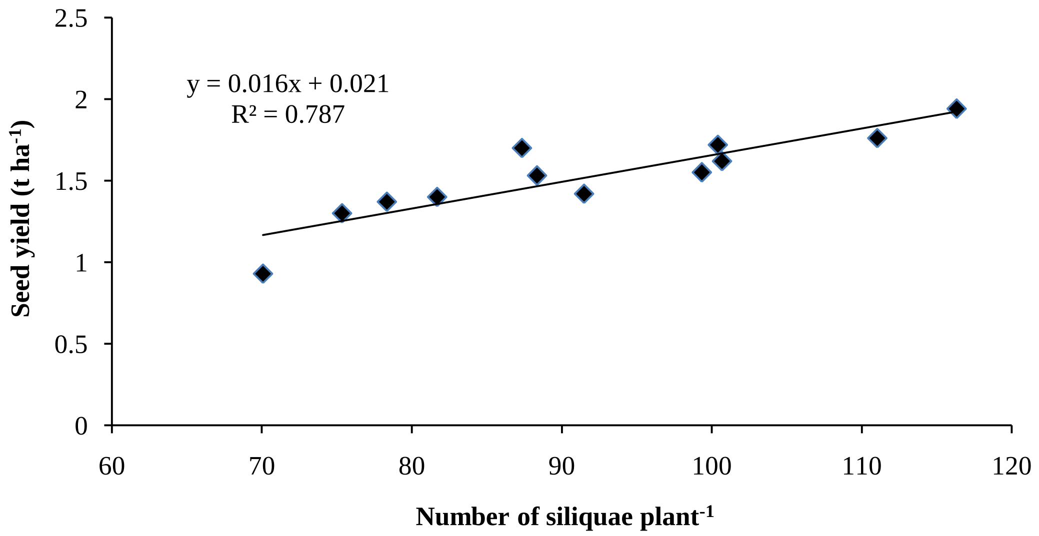


Figure 23. Relationship between number of siliquae plant^{-1} and seed yield (t ha^{-1}) of mustard varieties along with different zinc levels.

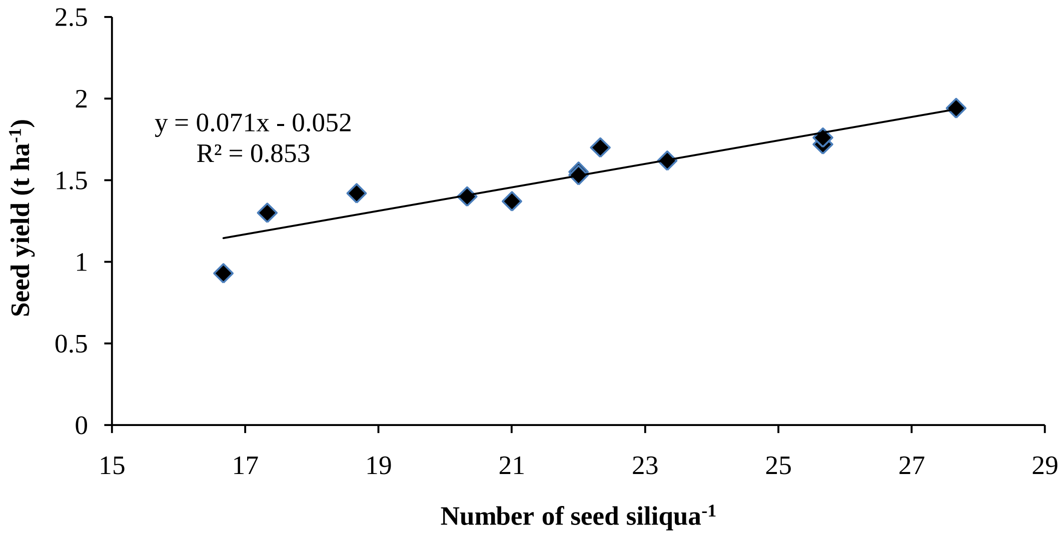


Figure. 24. Relationship between number of seed siliqua^{-1} and seed yield (t ha^{-1}) of mustard varieties along with different zinc levels.

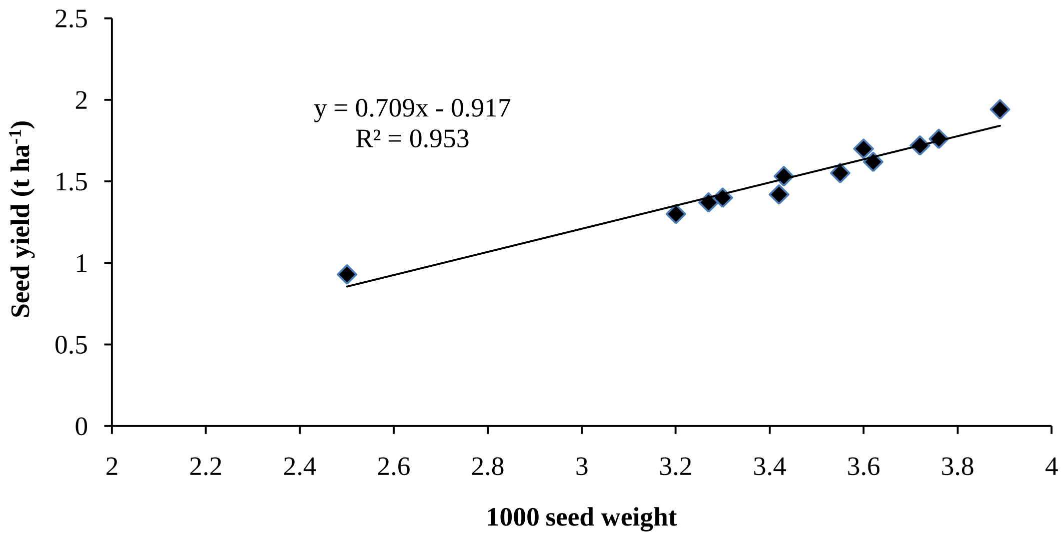


Figure 25. Relationship between 1000 seed weight and seed yield (t ha^{-1}) of mustard varieties along with different zinc levels.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Agronomy field of Sher-e-Bangla Agricultural University, Dhaka during the period from October-2019 to February 2020 in Rabi season to investigate the effects of zinc on growth and yield of mustard. The experiment consisted of two factors, and followed split-plot design with three replications. Factor A: Mustard varieties (2) *viz,* V_1= BARI Sarisha-14, V_2= BARI Sarisha-15 and Factor B: Different zinc levels (6) *viz*, Zn_0 = 0 kg ha^{-1}, Zn_1 = 1.00 kg ha^{-1}, Zn_2 = 2.0 kg ha^{-1}, Zn_3 = 3.00 kg ha^{-1}, Zn_4 = 4.0 kg ha^{-1} and Zn_5 = 5.00 kg ha^{-1}. Data on different parameters were collected for assessing results for this experiment and showed significant variation in respect of growth, yield and yield contributing characteristics of mustard due to the effect of different mustard varieties, zinc levels and their combinations.

In case of mustard varieties, BARI Sarisha-15 mustard variety (V_2) recorded the maximum plant height (10.98, 52.84, 84.53 and 94.25 cm) at 15, 30, 45 DAS and at harvest respectively. BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of branches $plant^{-1}$ (4.39, 7.88 and 10.61) and above ground dry matter weight $plant^{-1}$ (2.05, 5.10 and 34.79 g) at 30, 45 DAS and at harvest respectively. BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of siliqua $plant^{-1}$ (103.21), siliqua length $plant^{-1}$ (9.78 cm), number of seeds $siliqua^{-1}$ (23.84), 1000 seed weight (3.66 g), seed yield (1.67 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.57 t ha^{-1}) and harvest index (29.90 %). Whereas, BARI Sarisha-14 mustard variety (V_1) recorded the minimum plant height (10.09, 50.43, 75.53 and 85.55 cm) at 15, 30, 45 DAS and at harvest respectively. while BARI Sarisha-15 mustard (V_2) variety cultivation recorded the minimum number of branches $plant^{-1}$ (4.11, 6.78 and 9.66) and above ground dry matter weight $plant^{-1}$ (1.91, 4.89 and 32.09) at 30, 45 DAS and at harvest respectively. BARI Sarisha-15 mustard variety (V_2) cultivation recorded the minimum number of siliqua $plant^{-1}$ (80.18), siliqua length $plant^{-1}$ (8.10 cm), number of seeds $siliqua^{-1}$ (19.94), 1000 seed weight (3.22 g), seed yield (1.37 t ha^{-1}), stover yield $plant^{-1}$ (3.76 t ha^{-1}), biological yield (5.14 t ha^{-1}) and harvest index (26.52 %).

In case of different zinc levels, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum plant height (12.07, 60.63, 88.44 and 97.26 cm) at 15, 30, 45 DAS and at harvest respectively. 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of branches $palnt^{-1}$ (4.67, 8.88 and 11.83) at 30, 45 DAS and at harvest respectively. 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum above ground dry matter weight $plant^{-1}$ (2.79, 5.81, and 36.84 g) at 30, 45 and at harvest respectively. 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua $plant^{-1}$ (101.83), siliqua length $plant^{-1}$ (9.77 cm), number of seeds $siliqua^{-1}$ (23.84), 1000 seed weight (3.74 g), seed yield (1.82 t ha^{-1}), stover yield (4.07 t ha^{-1}), biological yield (5.89 t ha^{-1}) and harvest index (30.82 %). Whereas control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum plant height (8.47, 43.48, 73.32 and 79.24 cm) at 15, 30, 45 DAS and at harvest respectively. Control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of branches $palnt^{-1}$ (3.67, 5.77 and 8.33) at 30, 45 DAS and at harvest respectively. whereas 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum above ground dry matter weight $plant^{-1}$ (1.19, 4.26 and 28.72 g) at 30, 45 and at harvest respectively. Control or 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of siliqua $plant^{-1}$ (80.77), siliqua length $plant^{-1}$ (8.27 cm), number of seeds $siliqua^{-1}$ (17.67), 1000 seed weight (2.96 g), seed yield (1.18 t ha^{-1}), stover yield (3.42 t ha^{-1}), biological yield (4.59 t ha^{-1}) and harvest index (25.32 %).

In case of combined effect, cultivation of BARI Sarisha-15 mustard variety (V_2) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum plant height (12.56, 63.43, 97.49 and 103.06 cm) at 15, 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Z_5) treated plot recorded the maximum number of branches $plant^{-1}$ (4.67, 9.87 and 13.33) at 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum above ground dry matter weight $plant^{-1}$ (2.93, 5.82 and 38.11 g) at 30 , 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua $plant^{-1}$ (116.33), siliqua length $plant^{-1}$ (11.07 cm), number of seeds $siliqua^{-1}$ (27.67), 1000 seed weight (3.89 g), seed yield (1.94 t ha^{-1}), stover yield (4.16 t ha^{-1}), biological yield (6.10 t ha^{-1}) and harvest index (31.79 %). Whereas, cultivation of BARI Sarisha-

14 mustard variety along with 0 kg Zinc ha^{-1} (Zn_0) treated plot recorded the minimum plant height (7.94, 42.24, 63.90 and71.42 cm) at 15, 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of branches plant^{-1} (3.67, 5.29 and 8.00) at 30, 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum above ground dry matter weight plant^{-1} (1.09, 3.94 and 25.63 g) at 30 , 45 DAS and at harvest respectively. Cultivation of BARI Sarisha-15 mustard variety (V_2) along with 0 kg zinc ha^{-1} (Zn_0) treated plot recorded the minimum number of siliqua plant^{-1} (70.07), siliqua length plant^{-1} (7.97 cm), number of seeds siliqua^{-1} (16.67), 1000 seed weight (2.50 g), seed yield (0.93 t ha^{-1}), stover yield (3.17 t ha^{-1}), biological yield (4.10 t ha^{-1}) and harvest index (22.74%).

In case of correlation study, seed yield of mustard was positively correlated with number of siliqua plant^{-1} (R^2=0.787), number of seed siliqua^{-1} (R^2=0.853) and 1000-seeds weight (R^2=0.953) which was influenced by different mustard variety and zinc levels. In this experiment BARI Sarisha-14 mustard variety cultivation along with increasing zinc fertilization levels @ 5.00 kg ha^{-1} recorded maximum seed yield (1.94 t ha^{-1}) which was due to reason that BARI Sarisha-14 mustard variety along with increasing zinc levels produce higher number of siliqua plant^{-1} (116.33), seed siliqua^{-1} (27.67) and recoded maximum 1000-seeds weight (3.89) in comparable to others varieties in different levels of zinc fertilization.

Conclusion

Based on the above results of the present study, the following conclusions may be drawn

i. Among different mustard varieties, BARI Sarisha-14 mustard variety (V_1) cultivation recorded the maximum number of siliqua plant^{-1} (103.21), siliqua length plant^{-1} (9.78 cm), number of seeds siliqua^{-1} (23.84), 1000 seed weight (3.66 g), seed yield (1.67 t ha^{-1}), stover yield (3.90 t ha^{-1}), biological yield (5.57 t ha^{-1}) and harvest index (29.90 %).

ii. In the case of different zinc levels, 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua plant^{-1} (101.83), siliqua length plant^{-1} (9.77

cm), number of seeds siliqua^{-1} (23.84), 1000 seed weight (3.74 g), seed yield (1.82 t ha^{-1}), stover yield (4.07 t ha^{-1}), biological yield (5.89 t ha^{-1}) and harvest index (30.82 %).

iii. In the case of combined effect, cultivation of BARI Sarisha-14 mustard variety (V_1) along with 5.00 kg zinc ha^{-1} (Zn_5) treated plot recorded the maximum number of siliqua plant^{-1} (116.33), siliqua length plant^{-1} (11.07 cm), number of seeds siliqua^{-1} (27.67), 1000 seed weight (3.89 g), seed yield (1.94 t ha^{-1}), stover yield (4.16 t ha^{-1}), biological yield (6.10 t ha^{-1}), harvest index (31.79 %) and showed positive correlation between seed yield and yield contributing characters of mustard comparable to other treatments.

Recommendation for further work

Before making final conclusion, further trials with the same treatment combinations on different locations of Bangladesh would be useful. However, further investigation is necessary for the other soil types under different AEZ in Bangladesh.

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APPENDICES

Appendix I. Map showing the experimental location under study

Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

Morphological features	Characteristics
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

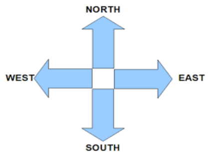
Sourse: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

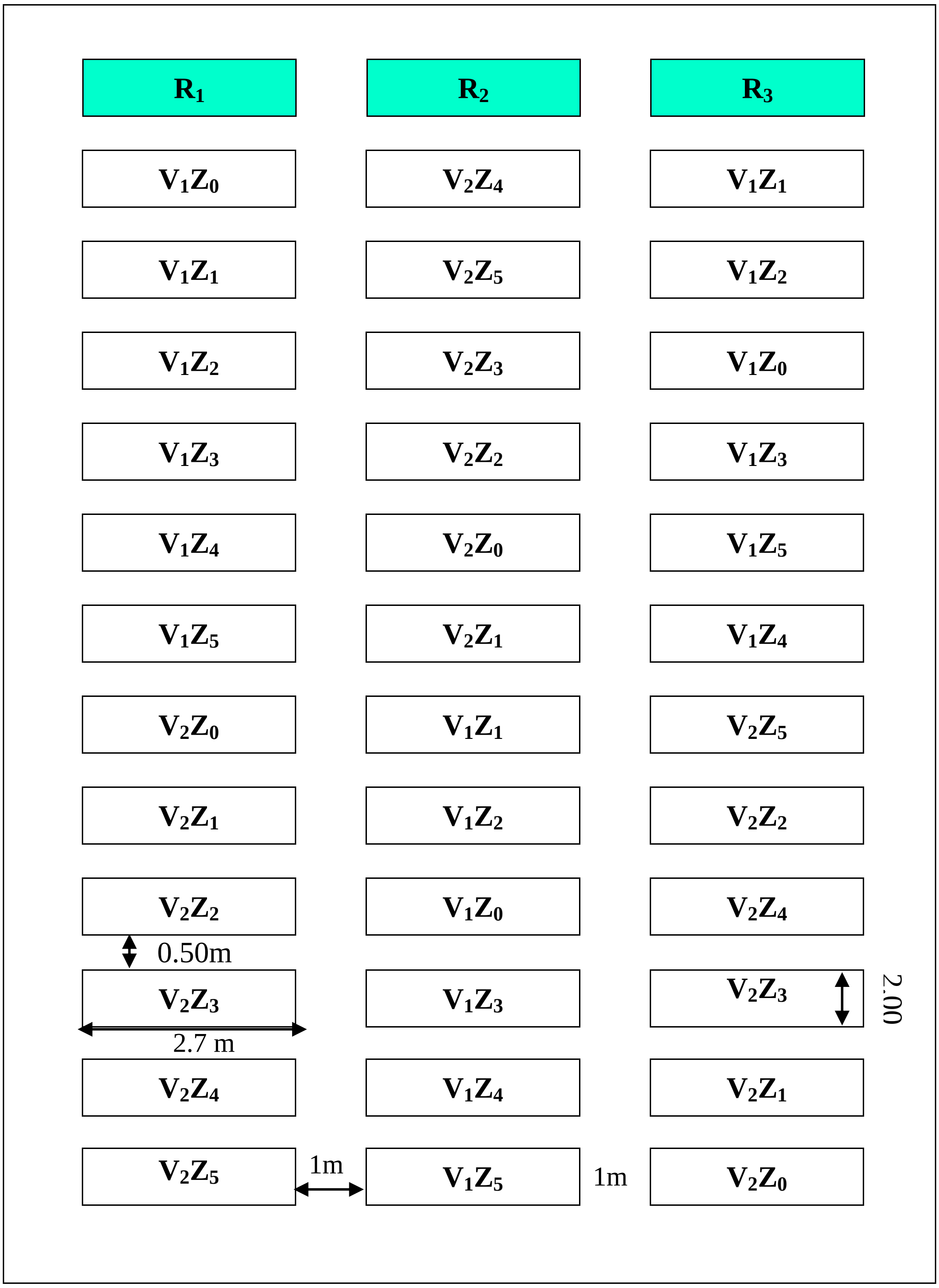
Appendix III. Monthly meteorological information during the period from October, 2019 to February 2020.

Year	Month	Air temperature (^{0}C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7

(Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Layout of the experimental field





LEGENDS

Here, V_1 = BARI Sarisha-14, V_2= BARI Sarisha-15, Zn_0 = 0 kg zinc ha^{-1}, Zn_1 =1.00 kg zinc ha^{-1}, Zn_2 = 2.0 kg zinc ha^{-1}, Zn_3 = 3.0 kg zinc ha^{-1}, Zn_4 = 4.0 kg zinc ha^{-1} and Zn_5 =5.00 kg zinc ha^{-1}.

Appendix V. Analysis of variance of the data of plant height of mustard at different DAS

Mean square of plant height at					
Source	**Df**	**15 DAS**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.62	5.33	11.44	8.33
Variety (V)	1	7.00*	52.42**	729.45*	681.21**
Error	2	0.08	0.33	12.44	1.00
Zinc levels (Z)	5	11.45**	211.59**	189.47**	218.72**
V×Z	5	1.76**	17.06**	109.65**	35.76**
Error	20	0.31	2.43	11.94	5.07
Total	35				

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of number of branches plant^{-1} of mustard at different DAS

Mean square of number of branches plant^{-1}				
Source	**Df**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.00907	0.2558	0.28436
Variety (V)	1	0.69722**	10.8241**	8.00890*
Error	2	0.00607	0.0925	0.19306
Zinc levels (Z)	5	1.04702**	7.9333**	9.30360**
V×Z	5	0.15663**	0.9399**	1.83292**
Error	20	0.00757	0.0942	0.15093
Total	35			

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of above ground dry matter weight of mustard at different DAT

Mean square of above ground dry matter weight at				
Source	**Df**	**30 DAS**	**45 DAS**	**At harvest**
Replication (R)	2	0.01116	0.02583	4.5216
Variety (V)	1	0.18063*	0.42250*	65.9073**
Error	2	0.00466	0.02083	0.6087
Zinc levels (Z)	5	2.70184**	1.83358**	47.2851**
V×Z	5	0.04053**	0.21700**	5.7020**
Error	20	0.00776	0.02333	1.1219
Total	35			

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of siliqua plant-^{1}, length of siliqua (cm) plant-^{1}, number of seeds siliqua^{-1} and 1000 seeds weight (g) of mustard

Mean square of					
Source	**Df**	**Number of siliqua plant^{-1}**	**Length of siliqua (cm)**	**Number of seeds siliqua^{-1}**	**1000 seeds weight (g)**
Replication (R)	2	11.58	0.2044	1.750	0.02721
Variety (V)	1	4772.74**	25.4016**	136.306*	1.76447**
Error	2	1.08	0.1002	1.750	0.00254
Zinc levels (Z)	5	372.17**	1.5071**	45.026**	0.42668**
V×Z	5	17.49**	0.3343*	3.260*	0.08477**
Error	20	3.53	0.0849	1.050	0.01488
Total	35				

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of seed yield, stover yield, biological yield (t ha^{-1}) and harvest index (%) of mustard

Mean square of					
Source	**Df**	**Seed yield (t ha^{-1})**	**Stover yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Replication (R)	2	0.01163	0.00239	0.02452	1.143
Variety (V)	1	0.79210**	0.16674*	1.68567**	102.887**
Error	2	0.00143	0.00887	0.01567	0.193
Zinc levels (Z)	5	0.28308**	0.33645**	1.20993**	20.315**
V×Z	5	0.01498*	0.08044**	0.14637**	2.713*
Error	20	0.00455	0.01193	0.01739	0.930
Total	35				

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability